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Remote Sensing for the Lincoln Sea Winterover Experiment

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Abstract

During the Naval Oceanographic and Atmospheric Research Laboratory (NOARL) Winterover experiment of 1989-1990, satellite imagery was processed in order to compare ice parameters derived from the imagery with the acoustic data collected. This effort is a continuation of an investigation of techniques developed during the Lincoln Sea exercise of 1990 (Fetterer et al.,1990).

Acknowledgments

Ms. Christine Mire of the Arctic Acoustics Branch of NOARL provided ambient noise data from the Buck Ambient Noise Model and from data collected during the Winterover experiment and provided valuable insight into that data. Dr. Ruth Preller and Ms. Pam Posey of the Ocean Hydrodynamic/Thermodynamic Branch at NOARL provided surface pressure and ice motion vectors for the Arctic from the Polar Ice Prediction System. Mr. Bobby Grant and Mr. Scott Nations of Sverdrup Technology processed imagery and provided convergence/divergence software, respectively. This work was supported by the Office of Naval Research under Program Element 0603704N, CDR P. Ranelli, Program Manager.

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REMOTE SENSING SUPPORT FOR THE LINCOLN SEA WINTEROVER EXPERIMENT

1. INTRODUCTION

The objective of this effort by the Naval Oceanographic and Atmospheric Research Laboratory (NOARL) Remote Sensing Branch is to support the collection of ambient noise data from the NOARL Winterover experiment. During several time periods in the Winterover exercise, the ambient noise records indicate that large events are present. The collection of satellite imagery during these critical times enables the scientist to investigate correlations between the ambient noise levels recorded at different frequencies and the movement of ice at the ocean's surface.

The NOARL Arctic Acoustics Branch left an ambient noise recording device below the ice in the Lincoln Sea at the end of the 1989 exercise. The device was retrieved during an exercise in April 1990. The data were then processed and analyzed to ambient noise levels at various frequencies. The NOARL Remote Sensing Branch acquired National Oceanographic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) imagery for the periods requested by the NOARL Winterover group.

2. DATA ANALYSIS

A vertical array of hydrophones remained in the Lincoln Sea area following abandonment of a camp manned by NOARL as part of a Winterover exercise. The omnidirectional vertical array sampled ambient noise at hourly intervals from March 1989 until it was retrieved in April 1990. The NOARL Remote Sensing Branch requested that NOAA collect AVHRR imagery from the Lincoln Sea region during the Winterover exercise. Following recovery of the array and analysis of the ambient noise data, several periods of interest were discovered. NOARL acquired imagery for these periods (Table 1). The processing that was performed on these images is described in the following paragraphs.

Table 1. AVHRR Imagery Acquired for Lincoln Sea Analysis.

Image Name	Time(GMT)	Comments
LS_04DEC89_LSUB	1416	Good, some clouds
LS_05DEC89_LSUB	1547	Good, clouds
LS_07DEC89_LSUB	1526	Good, high clouds
LS_15DEC89_LSUB	1542	Fair
LS_21DEC89_LSUB	1437	Good, coastal clouds
LS_22DEC89_LSUB	1426	Fair, dropouts
LS_23DEC89_LSUB	1415	Good, some clouds
LS_24DEC89_LSUB	1547	Good, clouds
LS_25DEC89_LSUB	1536	Very good, high clouds
LS_08JAN90_LSUB	1446	Good
LS_10JAN90_LSUB	1424	Good, some high clouds
LS_12JAN90_LSUB	1545	Very good
LS_18JAN90_LSUB	1443	Poor, cloudy
LS_20JAN90_LSUB	1421	Poor, cloudy
LS_21JAN90_LSUB	1549	Good, floe visible
LS_24JAN90_LSUB	1520	Good, clouds
LS_02MAR90_LSUB	1522	Good, clouds

Table 1. (con't)

LS_05MAR90_LSUB	1450	Poor, cloudy
LS_10MAR90_LSUB	1541	Excellent, dropout
LS_13MAR90_LSUB	1508	Very good, few clouds
LS_16MAR90_LSUB	1435	Good, dropouts
LS_17MAR90_LSUB	1420	Good, clouds, dropout

The 1.1 km (resolution at nadir) AVHRR channel 4 infrared imagery is processed using standard packages available at the NOARL Remote Sensing Branch. Each image is mapped to a polar stereographic projection and calibrated. Figure 1 shows the area covered by each image. These images are perused to determine their usefulness for analysis of sea ice leads. A description of the processing done on the imagery is contained in Fetterer et al. (1990) and will not be repeated in this document. The results of these processing steps for the Winterover are provided in Table 2.

Table 2. Summary of AVHRR Imagery Processing.

Image	BI	CF	DAT	ACC	ROSE	STAT	OR	GREY
O4DEC89	X	X	X	X	X	X	X	X
05DEC89	X	X	X	X	X	X	X	X
07DEC89	X	X	X	X	X	X	X	X
15DEC89								
21DEC89	X	X	X	X	X	X	X	X
22DEC89	X	X	X	X	X	X	X	X
23DEC89	X	X	X	X	X	X	X	X
24DEC89	X	X	X	X	X	X	X	X
25DEC89	X	X	X	X	X	X	X	X
08JAN90	X	X	X	X	X	X	X	X
10JAN90	X	X	X	X	X	X	X	X
12JAN90	X	X	X	X	X	X	X	X
18JAN90								
20JAN90								
21JAN90	X	X	X	X	X	X	X	X
24JAN90	X	X	X	X	X	X	X	X
02MAR90	X	X	X	X	X	X	X	X
05MAR90	X	X	X	X	X	X	X	X
10MAR90	X	X	X	X	X	X	X	X
13MAR90	X	X	X	X	X	X	X	X
16MAR90	X	X	X	X	X	X	X	X
17MAR90	X	X	X	X	X	X	X	X

LEGEND

BI	=	Binary Image	CF	=	Cloud-free Image
DAT	=	Data File	ACC	=	Accumulator File

ROSE =	Rose Plot	STAT =	Statistics File
OR =	Orientation Plot	GREY =	Grey Level Image

The imagery processed for the Winterover exercise indicates several natural breaks in the data. The period 04-07 December constitutes the early December data set. A second consistent set occurs in December. This set includes 21, 22, 23, and 25 December 1989. The image for 15 December was selected as a transition image, but it is very cloudy. The image for 24 December is also very cloudy and provides little information about the leads. A third data set encompasses the period 08-12 January 1990. The imagery for this set, 8, 10, and 12 January, is some of the best of the Winterover period. The images for 18, 20, 21, and 24 January were elimated from consideration because of the number of clouds in the imagery. A final data set was selected during March. The imagery from 10, 13, 16, and 17 March is used in the analysis of this March time period. The 02 and 05 March 1990 imagery is used for information purposes only. These time periods, which are used throughout the remainder of this document, are provided in Table 3.

Table 3. Time periods for Winterover analysis.

Period 1. Early December 1989	04 December 1989 05 December 1989 07 December 1989
Period 2. Late December 1989	21 December 1989 22 December 1989 23 December 1989 24 December 1989 25 December 1989
Period 3. January 1990	08 January 1990 10 January 1990 12 January 1990
Period 4. March 1990	10 March 1990 13 March 1990 16 March 1990 17 March 1990

Fields from the Polar Ice Prediction System (PIPS) are included with the image-derived information in this note (Preller and Posey, 1989). PIPS initializations are provided by the Navy Operational Global Atmospheric Prediction System (NOGAPS). Because serious problems were encountered by NOGAPS during December and January of the Winterover experiment, the results of PIPS during some time periods are questionable. The PIPS time periods in question are the following:

Dec 6 and 7	missing
Dec 17 and 20	missing
Dec 21 and 22	too much ice, NOGAPS problem
Dec 23 thru 27	bad NPOC updates
Jan 11 thru 20	too much ice
Jan 17 and 21 thru 22	missing
Mar 13 and 15	missing

Unfortunately each of these periods coincides with a period of interest for the Winterover exercise.

Each 512 x 512 image was divided into 64 x 64 km blocks. Lead statistics were calculated for all of the leads found within each image block. Figure 2 shows the block numbers for the image area. The orientation (in degrees relative to the top of each image) and size (in square km) of all leads in each block with a size greater than 20 km^2 was found. See, for example, Table 4. Block 22 shows that 2 large leads were found, one with orientation 157° and size 91 km^2, the other with orientation 166° and size 48 km^2. An X in a block means that no leads greater than 20 km^2 were found, while a blank block contained land or clouds. Lead spacings and widths for various orientations in each image are also found (see for example Table 5). The first entry in Table 5, for instance, means that if one were to transect the image on a straight line oriented 30° from vertical, the average spacing between leads would be 14.4 km.

In addition to lead statistics, ice motion vectors were found for pairs of images. The algorithm for arriving at the vectors is briefly described in Fetterer et al. (1990). See the List of Figures for the location of ice motion vector images and results.

3. RESULTS

The analysis results are presented as a series of tables and figures for each of the four periods of interest. Tables are included in this note with the numbered text pages, while all figures, for convenience, are at the end of the note. Consult the List of Figures for the figure number corresponding to the image from which each table's information was derived. Tables 4 through 34 show lead orientation and spacing statistics for each image. These are followed by tables showing the open-water fraction for each image within each of the 4 periods of interest, with a summary of conditions for each period (Tables 35 through 38). Table 35, for instance, shows the percent open water (that is, lead fractional coverage) by block for 4, 6, and 7 December. A *C* in a column indicates that block was cloudy. The section of results concludes with a discussion of the correlation between ambient noise and open-water fractions, which is summarized in Tables 39 through 45.

Table 4. 04 December 1989 Lead Orientation and Size by Block.

1	2	3	4	5	6	7 90 42	8 143 61
9	10	11	12	13	14	15	16
17 X	18	19 153 111	20 X	21 169 58	22 157 91 166 48	23 14 150 168 54	24 149 76 158 45
25	26	27	28	29 145 57	30 X	31	32
33	34	35 X	36 110 42	37 117 59	38 107 70 135 64 131 62	39 91 53	40 118 90 78 66
41	42	43	44	45	46	47	48

Table 5. 04 December 1989 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
30.0	14.4	18.5	1.4	0.9
45.0	19.6	24.6	1.6	0.9
60.0	10.3	16.6	1.8	1.0
75.0	19.3	46.5	1.8	1.1
90.0	11.9	26.6	1.9	1.2
105.0	7.7	18.4	1.9	1.4
120.0	10.0	22.4	2.0	1.5
135.0	17.0	26.9	1.8	1.3
150.0	12.9	20.0	1.6	1.0
165.0	12.1	15.4	1.2	0.6
180.0	14.9	30.6	2.0	1.7

Table 6. 05 December 1989 Lead Orientation and Size by Block.

1 62 44	2 90 32	3 174 67 90 47	4	5	6	7 X	8 90 42
9 12 30	10 X	11	12 X	13 176 29	14 172 55	15 165 69	16 164 46
17	18	19 150 94	20 X	21 X	22 157 48	23 15 86	24
25	26	27 X	28 131 69	29 148 48	30	31	32
33	34	35	36 X	37 X	38	39	40
41	42	43	44	45	46	47	48

Table 7. 05 December 1989 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
30.0	21.6	22.8	1.3	0.7
45.0	36.2	39.8	1.5	0.8
60.0	22.5	29.6	1.7	1.5
75.0	15.4	29.4	1.6	0.8
90.0	41.6	87.3	1.7	1.1
105.0	42.1	87.4	2.0	1.2
120.0	61.8	99.1	1.8	1.1
135.0	19.7	28.1	1.4	0.7
150.0	21.3	35.5	1.4	0.6
165.0	2.1	3.8	1.3	0.5
180.0	10.9	28.6	2.0	1.4

Table 8. 07 December 1989 Lead Orientation and Size by Block.

1 X	2	3	4	5	6	7	8
9	10	11	12	13	14 155 47	15 X	16 X
17	18	19 150 58	20	21 X	22 169 40	23	24 149 76
25 X	26	27 X	28 X	29 X	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48

Table 9. 07 December 1989 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
45.0	2.9	4.9	2.0	1.2
60.0	4.1	8.7	2.2	1.8
75.0	8.6	24.0	2.0	1.3
90.0	7.2	17.0	2.4	2.2
105.0	9.1	24.7	2.4	2.1
120.0	10.8	27.2	2.3	1.6
135.0	23.9	59.1	1.9	1.3
150.0	17.9	40.1	1.6	1.1
165.0	5.5	14.8	1.3	0.6
180.0	7.0	27.2	2.3	1.6

Table 10. 21 December 1989 Lead Orientation and Size by Block.

1	2 129 33	3 125 43 90 40	4 X	5	6	7	8 2 77
9	10 X	11 X	12 127 81 139 46	13 122 89	14 X	15	16 7 151 177 48
17	18	19 X	20 X	21 X	22 127 101	23 X	24 164 70 163 69 125 63
25	26	27 X	28 X	29 X	30 X	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48

Table 11. 21 December 1989 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
30.0	14.2	20.2	1.4	0.8
45.0	24.9	32.1	1.6	0.9
60.0	18.8	32.1	1.6	0.9
75.0	24.7	45.4	2.0	0.9
90.0	16.5	40.3	1.8	1.1
105.0	27.3	55.8	1.7	0.9
120.0	36.1	75.0	1.9	1.1
135.0	14.7	24.0	2.0	2.0
150.0	12.7	22.1	1.6	0.9
165.0	3.7	5.3	1.4	0.7
180.0	11.8	25.8	2.2	2.5

Table 12. 22 December 1989 Lead Orientation and Size by Block.

1 X	2 X	3 135 52	4 X	5 X	6	7	8 X
9 X	10 X	11 X	12 136 60 132 53	13	14	15 X	16 6 115
17 X	18 X	19 X	20	21	22 130 75	23 X	24 170 45 164 41
25 X	26 X	27	28	29 X	30 X	31 125 50	32 128 38
33 X	34	35	36 X	37 X	38 X	39 X	40 X
41	42	43	44	45	46	47	48

Table 13. 22 December 1989 Lead Spacing and Width with Orientation

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
15.0	21.7	23.3	1.1	0.3
30.0	24.9	30.7	1.2	0.5
45.0	26.1	31.8	1.5	1.3
60.0	21.3	39.9	1.6	0.8
75.0	38.2	60.9	1.4	0.7
90.0	34.1	67.6	1.6	0.9
105.0	49.6	88.2	1.6	0.9
120.0	44.9	76.5	1.6	0.8
135.0	36.9	48.4	1.7	1.5
150.0	16.7	31.2	1.4	0.7
165.0	10.4	10.0	1.2	0.6
180.0	29.5	53.1	1.7	1.4

Table 14. 23 December 1989 Lead Orientation and Size by Block.

1	2	3	4 44 338 151 79 90 78	5	6	7	8 156 96 90 94 174 89
9	10	11	12	13	14	15	16 162 244
17	18	19	20	21	22 127 79 135 66 142 55	23 152 129 135 68	24 X
25	26	27	28	29	30 X	31 123 182 106 53	32 107 91 126 63
33	34	35	36	37	38	39 X	40 X
41	42	43	44 X	45 X	46 X	47 X	48

Table 15. 23 December 1989 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
30.0	12.7	18.5	1.6	0.9
45.0	13.0	21.8	1.7	1.0
60.0	12.6	28.5	2.0	1.6
75.0	4.4	8.0	2.0	1.6
90.0	5.7	21.3	2.2	1.7
105.0	9.4	34.5	2.1	1.6
120.0	9.0	29.6	2.0	1.3
135.0	11.7	25.0	2.1	2.3
150.0	12.3	29.6	1.7	1.1
165.0	5.4	7.1	1.5	1.0
180.0	12.0	38.2	2.3	1.8

Table 16. 24 December 1989 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
180.0	1.0	2.4	2.5	2.2

Table 17. 25 December 1989 Lead Orientation and Size by Block.

1	2	3	4	5	6 89 68	7 90 75 177 46	8 167 72 90 56
9	10	11	12	13 122 88	14 155 87	15 136 139 167 71	16 169 48
17	18	19 124 84 146 55 147 55	20 155 98 141 65 159 59	21 135 147 144 96 159 84	22 122 162	23 120 68 128 67 150 59	24
25	26	27 127 63	28 135 244 125 157	29 135 112 102 46	30 108 203 124 68	31	32
33	34	35	36	37 108 127	38 99 176	39 87 105	40 X
41	42	43	44	45	46 X	47	48

Table 18. 25 December 1989 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
30.0	11.7	17.1	1.4	0.6
45.0	10.7	14.1	1.8	0.9
60.0	7.6	12.9	2.0	1.1
75.0	10.1	24.2	2.1	1.4
90.0	6.4	15.7	2.5	2.9
105.0	8.4	17.3	2.3	1.9
120.0	11.4	21.4	2.1	1.4
135.0	14.1	24.0	2.4	2.2
150.0	7.0	13.4	2.1	1.4
165.0	9.7	14.0	1.4	0.8
180.0	8.7	25.7	2.5	1.6

Table 19. 08 January 1990 Lead Orientation and Size by Block.

1 90 84 82 71	2 89 83 85 70 57 56	3 88 82 89 68 85 55	4 60 158 96 58 89 56	5 83 139 101 80 49 75	6	7	8
9 160 99	10 124 39	11 50 59	12 83 40	13 74 108 65 80	14 100 131 65 72	15	16
17 165 102 159 100 149 77	18 174 99 157 46	19 78 94 135 65 128 60	20 77 131	21	22	23	24
25	26	27	28	29	30	31	32
33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48

Table 20. 08 January 1990 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
30.0	6.7	16.3	1.7	1.0
45.0	21.4	38.2	2.5	2.1
60.0	17.6	43.1	2.3	1.7
75.0	2.4	5.7	2.5	2.3
90.0	8.4	20.2	2.1	1.5
105.0	5.6	15.0	2.5	2.2
120.0	3.4	9.2	2.5	2.4
135.0	5.1	6.8	1.7	1.0
150.0	6.4	7.6	1.4	0.7
165.0	3.9	4.1	1.3	0.5
180.0	2.6	6.0	2.0	1.0

Table 21. 10 January 1990 Lead Orientation and Size by Block.

1 90 84 82 71	2 89 83 85 70 57 56	3 88 82 89 68 85 55	4 60 158 96 58 89 56	5 83 139 101 80 49 75	6	7	8
9 160 99	10 124 39	11 50 59	12 83 40	13 74 108 65 80	14 100 131 65 72	15	16
17 165 102 159 100 149 77	18 174 99 157 46	19 78 94 135 65 128 60	20 77 131 83 63	21 77 172 45 76	22 92 128 76 120	23 106 150 76 95	24 124 116 109 108 62 103
25 152 78 157 65	26 141 151 142 138 148 76	27 138 121 151 114 152 74	28 123 55	29 135 136 76 49	30 92 114	31 76 120 102 70	32 71 110 138 96
33 134 60 102 43	34 82 123	35 64 64 89 42	36 X	37 101 138 110 72 117 55	38 90 80	39 90 98 122 67	40 85 108
41	42	43	44	45	46	47	48

Table 22. 10 January 1990 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
15.0	7.0	7.1	1.1	0.4
30.0	6.7	8.4	[illegible].5	0.8
45.0	8.3	10.4	1.8	1.3
60.0	5.6	10.4	2.0	1.4
75.0	8.2	16.3	2.0	1.6
90.0	6.6	15.1	2.3	2.0
105.0	6.9	14.8	2.3	2.2
120.0	8.8	16.0	2.2	1.9
135.0	8.8	11.9	2.0	1.5
150.0	7.5	8.3	1.4	0.8
165.0	5.9	6.6	1.2	0.5
180.0	5.9	11.0	2.1	1.6

Table 23. 12 January 1990 Lead Orientation and Size by Block.

1	2 79 98 112 61 89 50	3 86 116 78 68 89 45	4 65 86 97 46	5 85 101	6 105 91 77 81 71 76	7 73 84 61 72	8
9	10	11 84 91 95 51	12 98 146 88 89	13 76 46 75 40 66 40	14 X	15 112 102 70 68 80 66	16 50 177 91 72
17	18 88 54 115 41	19 78 137	20 78 150	21 77 123	22 95 116 77 97	23 107 211 80 85	24 125 219 61 56
25 125 69 158 45	26 144 148	27 135 62 152 62	28 104 74 100 49	29 81 76 100 56 105 45	30 93 107	31	32 71 109 143 68 134 60
33 135 32	34 X	35 65 53	36 101 146	37 101 112	38 92 126	39 90 113 121 51	40
41	42	43	44	45	46	47	48

Table 24. 12 January 1990 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
15.0	8.6	9.6	1.1	0.3
30.0	8.3	9.8	1.4	0.6
45.0	8.8	13.3	1.9	1.1
60.0	8.4	15.4	2.1	2.0
75.0	8.4	15.7	2.2	1.8
90.0	7.7	19.6	2.5	2.2
105.0	8.9	22.2	2.6	2.5
120.0	9.6	20.4	2.4	2.5
135.0	10.6	14.2	1.8	1.2
150.0	8.6	10.3	1.4	0.8
165.0	5.7	7.2	1.2	0.5
180.0	6.8	13.9	2.0	1.2

Table 25. 02 March 1990 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
30.0	18.3	29.1	1.4	0.8
45.0	38.5	48.9	1.5	0.9
60.0	18.7	33.6	1.8	1.6
75.0	17.7	42.0	2.0	1.5
90.0	21.3	49.5	2.1	1.6
105.0	21.5	41.5	1.8	1.4
120.0	25.1	48.6	2.0	1.8
135.0	26.2	44.5	1.6	1.0
150.0	25.5	35.4	1.5	0.8
180.0	20.2	47.0	2.0	1.5

Table 26. 05 March 1990 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
15.0	13.1	14.9	1.2	0.4
30.0	15.7	17.1	1.3	0.7
45.0	19.7	20.5	1.5	0.9
60.0	12.2	19.7	1.6	0.7
75.0	8.8	16.2	1.7	1.1
90.0	10.8	20.3	1.8	1.1
105.0	13.2	25.9	2.0	1.3
120.0	12.2	23.7	1.8	1.1
135.0	9.8	18.5	1.9	1.6
180.0	15.2	29.9	1.9	1.4

Table 27. 10 March 1990 Lead Orientation and Size by Block.

1	2	3	4	5 134 48	6 X	7 X	8 X
9	10	11 134 46	12	13 141 94	14 175 43	15	16
17 X	18 X	19 138 68	20 X	21 X	22 165 57 149 51	23 154 86 168 75	24 133 61
25	26 X	27 110 40	28 135 51	29 131 125 144 42	30 X	31 123 67	32 4 104 12 58 118 54
33 X	34 61 46	35 X	36 X	37 X	38 105 85 102 53	39 122 53	40 90 71
41	42	43	44	45	46	47	48

Table 28. 10 March 1990 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
15.0	9.9	9.2	1.1	0.3
30.0	15.6	17.9	1.3	0.5
45.0	19.9	21.3	1.5	0.8
60.0	13.3	20.0	1.7	0.9
75.0	13.1	25.7	1.8	1.1
90.0	13.0	29.3	2.0	1.3
105.0	16.9	32.4	1.9	1.3
120.0	15.6	28.7	1.9	1.1
135.0	23.4	38.7	1.6	1.2
150.0	12.8	16.7	1.6	0.9
165.0	7.9	8.5	1.2	0.5
180.0	11.6	22.7	1.8	1.1

Table 29. 13 March 1990 Lead Orientation and Size by Block.

1	2	3	4	5 134 48	6 X	7 X	8 X
9	10	11 134 46	12	13 141 94	14 176 46	15 142 63	16 X
17	18 107 74	19 141 85	20	21 X	22 150 74	23 X	24
25 84 49 102 48	26 92 96	27	28	29 127 155 128 79	30 156 36	31 X	32
33 120 51	34 X	35 83 60 96 59	36	37 X	38 X	39 X	40 93 37
41	42	43	44 X	45	46 X	47 X	48

Table 30. 13 March 1990 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
15.0	11.8	12.8	1.1	0.3
30.0	20.5	24.7	1.2	0.5
45.0	23.3	31.2	1.5	0.7
60.0	21.6	34.9	1.5	0.7
75.0	16.8	33.0	1.8	1.1
90.0	14.5	37.6	2.0	1.2
105.0	15.5	36.7	1.9	1.2
120.0	21.7	38.7	1.8	1.4
135.0	18.5	27.0	1.7	1.2
150.0	18.8	23.7	1.5	1.0
165.0	14.5	17.7	1.1	0.4
180.0	13.5	27.6	1.7	1.1

Table 31. 16 March 1990 Lead Orientation and Size by Block.

1 X	2 144 137 167 66	3 X	4 X	5 141 91	6 X	7 150 70	8
9 X	10 135 67	11 146 119	12 X	13 X	14	15	16
17 94 41	18 X	19	20 X	21 X	22	23	24
25 94 120	26 89 121 90 48 132 58	27 110 74 99 64 107 60	28 106 115 135 55 104 47	29	30	31 X	32
33	34	35 84 37	36	37	38 99 62	39 X	40
41	42	43	44	45	46 X	47 X	48

Table 32. 16 March 1990 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
15.0	11.6	12.5	1.1	0.4
30.0	15.6	18.8	1.2	0.5
45.0	19.0	25.1	1.5	0.7
60.0	12.7	20.9	1.6	0.9
75.0	17.4	34.8	1.9	1.2
90.0	13.3	31.7	2.1	1.6
105.0	19.0	36.8	2.0	1.6
120.0	19.8	32.4	1.9	1.4
135.0	22.8	35.2	1.7	1.2
150.0	26.7	43.8	1.6	1.5
180.0	15.5	35.8	1.8	1.1

Table 33. 17 March 1990 Lead Orientation and Size by Block.

1 X	2 143 137 167 67	3	4	5 160 65	6 1 108	7	8 148 47
9	10	11	12	13 X	14 176 97	15 144 76	16
17	18	19 X	20 X	21 X	22 152 74 165 69	23 144 52	24 134 88
25	26 88 107 89 68 93 59	27 107 81 105 80	28 107 113 106 112	29 135 84 114 72 130 54	30 X	31 135 45	32 6 103 135 38
33	34 X	35 X	36 X	37	38	39	40
41	42	43 135 95 92 93 109 90	44 108 69 90 60	45 86 179 134 67 141 58	46 X	47 X	48

Table 34. 17 March 1990 Lead Spacing and Width with Orientation.

Orientation (deg)	Mean Spacing (km)	Std. Dev. Spacing	Mean Width (km)	Std. Dev. Width
15.0	9.6	9.5	1.1	0.3
30.0	16.8	19.5	1.3	0.5
45.0	19.6	23.1	1.5	0.8
60.0	16.5	29.3	1.9	1.2
75.0	11.6	27.5	1.8	1.1
90.0	12.7	28.1	2.1	1.8
105.0	15.6	34.1	1.9	1.3
120.0	13.7	25.7	2.1	1.8
135.0	15.3	26.6	1.9	1.1
150.0	11.8	20.5	1.6	1.1
165.0	6.2	8.5	1.4	0.8
180.0	12.4	26.5	1.8	1.2

Summary, Early December Conditions

Surface pressure charts generated by NOGAPS indicate that winds are from the northwest and onshore during the early December period. Imagery indicates that the amount of open water is less for 05 December than 04 December. There is a large amount of fractured ice in the nearshore region. Motion vectors indicate little motion for the period between the two images. The motion vectors for the period 05 to 07 December indicate that ice motion is onshore in the center of the region and is moving out at the boundaries. The ice is moving eastward on the eastern boundary and westward on the western boundary. Comparing the amount of open water derived from the imagery is another way to compare what is happening to the ice in this region. The amount of open water in the entire image dropped from approximately 6% on 04 December to approximately 3% on 05 December. That is a 50% decrease in the amount of open water present in approximately 24 hours. As the amount of open water decreases, an increase in the amount of ice touching neighbors and ridge formation is expected and noise should be on the rise. The next image on 07 December indicates convergence of the ice and less open water.

Comparison of individual blocks that are common to all three images is another way to examine the data. For all of the common blocks, and for Block 21 in particular, the decrease in open water mirrors the decrease using all of the blocks available in each image (Table 35). Block 22 shows a slightly different reaction. During the period between 05 and 07 December, there is slightly more open water in this block. The percentage of open water increases from 2.7 to 3.2%. The area that contains this block is in the region where the ice moving directly toward the coast is diverging from the ice that is beginning to move eastward toward Fram Strait.

The orientations of the leads in this region remain relatively constant at approximately 150°. The ice is tightly packed during the height of the winter season and the onshore wind pushes it more tightly. As a result, there can be little shifting of the ice and little movement of the orientation of the ice leads.

The ambient noise for this time period is presented in Figure 13. One line is the actual daily average of noise collected during the Winterover and the other is daily average noise generated using the Buck Ambient Noise Model (Buck and Rosser, 1982) with ice motion vectors and winds from the PIPS as input.

Table 35. Open-Water Fraction Early December 1989.

Block	Percent Open Water		
	04 Dec	05 Dec	07 Dec
1	0.0	5.2	2.9
2	0.0	1.9	0.0
3	0.0	4.3	0.0
7	6.3	1.0	0.0
8	14.5	5.8	0.0
9	0.0	4.0	0.0
10	0.0	0.9	0.0
12	0.0	0.5	0.0
13	0.0	1.2	0.0
14	0.0	4.4	4.1
15	0.0	4.2	2.4
16	0.0	6.3	5.3
17	1.2	0.0	0.0
18	0.0	0.0	0.1

Table 35. (con't.)

19	6.4	3.1	2.5
20	3.0	1.8	0.0
21	6.2	2.1	1.2
22	5.9	2.7	3.2
23	9.1	5.6	0.0
24	12.2	0.0	7.7
25	0.0	0.0	0.8
26	0.5	0.0	0.0
27	C	0.5	0.4
28	C	2.7	2.1
29	4.3	2.8	1.2
30	8.0	C	C
34	0.2	C	C
35	0.7	C	C
36	2.4	1.9	C
37	3.1	1.1	C
38	9.7	C	C
39	8.8	C	C
40	6.7	C	C
55	C	C	7.6
56	C	C	26.0

Summary, Late December Conditions

The imagery from the period 21 and 22 December indicates closing of the lead area in this region. Ice motion is from Greenland in the east into the Lincoln Sea area. Motion vectors generated from the two images show very short ice motion vectors. Light winds dominate through 23 December, then westerlies generated by a polar low are prevalent. PIPS indicates eastward ice motion, which is stronger on 24 December than 25 December. Ice motion vectors indicate eastward motion in the upper half of the images. There is little or no movement or opening in Blocks 37, 38, 39, and 40.

The figure showing percent open water indicates closing of the leads for the period 21 to 22 December, then opening. The opening occurs first during the period 22 to 23 December in Blocks 16 and 23, in the east of the image, then in Block 30 during the two date period 23 to 25 December, which is south of the first two blocks. The ambient noise for this period is presented in Figure 28.

Table 36. Open-Water Fraction Late December 1989.

Block	Percent Open Water				
	21 Dec	22 Dec	23 Dec	24 Dec	25 Dec
1	C	1.3	C	C	C
2	4.5	3.5	C	C	C
3	7.3	6.2	C	C	C
4	1.0	0.6	28.1	C	C
5	C	1.2	C	C	C
6	C	C	C	C	5.9
7	C	C	C	C	5.7

Table 36. (con't.)

8	7.3	3.8	17.0	C	9.5
9	C	2.3	C	C	C
10	1.0	1.2	C	C	C
11	1.6	1.4	C	C	C
12	5.1	4.2	C	C	C
13	2.6	C	C	C	3.5
14	1.5	C	C	C	4.8
15	C	0.8	C	C	9.9
16	12.3	5.6	11.7	C	5.8
17	C	1.0	C	C	C
18	C	0.9	C	C	C
19	1.8	1.8	C	C	11.1
20	0.8	C	C	C	13.6
21	2.8	C	C	C	13.8
22	5.3	3.4	9.1	C	8.8
23	6.7	3.5	9.4	C	9.1
24	14.2	7.0	5.2	C	C
25	C	1.8	C	C	C
26	C	2.1	C	C	C
27	0.8	C	C	C	3.2
28	1.1	C	C	C	12.7
29	1.9	1.2	C	C	7.9
30	3.1	1.7	4.2	C	11.7
31	C	4.4	9.2	C	C
32	C	5.5	11.5	C	C
33	C	2.6	C	C	C
35	C	C	0.2	C	0.2
36	C	0.7	0.2	C	0.2
37	C	0.6	0.2	C	5.2
38	C	0.9	0.3	4.5	6.9
39	C	1.9	0.3	3.0	4.0
40	C	1.5	0.7	0.1	0.6
44	C	1.7	0.9	0.6	C
46	C	1.9	1.6	0.8	0.9
47	C	C	1.4	C	0.1

Summary, January Conditions

There are two dominant features visible in the infrared imagery for the region during the January period of interest. The first of these is a lead aligned along 84° N. This lead is similar to leads detected in the past in this location and may be a semipermanent feature. The second feature is a very straight lead running in a southwest to northeast configuration from 84 to 86° N.

Large amounts of open water are present. The percent open water tables shows that the period begins with greater than 10% open water. The amount of open water increases to approximately 11% on 10 January and decreases to 9% on 12 January. The opening in Block 28 shows an increase in open water from 6 to 16%. The percent open water for the imagery shows little change from 8 to 10 to 12 January, but the individual blocks show much more change.

Motion vectors indicate that two regimes exist for the period 10 to 12 January. North of the straight lead, ice motion is out of the southwest in the west, eastward in the center of

the region, and to the southeast in the eastern portion of the region. Below the lead, there is little movement. PIPS indicates offshore motion of ice on 12 January. The ambient noise for this period is shown in Figure 38.

Table 37. Open-Water Fraction January 1990.

Block	Percent Open Water		
	08 Jan	10 Jan	12 Jan
1	C	9.5	C
2	C	8.1	11.1
3	C	10.0	11.4
4	C	9.3	5.9
5	C	19.1	11.6
6	C	C	12.1
7	20.7	C	12.3
8	13.7	C	C
9	C	8.3	C
10	C	5.3	C
11	C	6.6	10.6
12	C	8.6	12.0
13	C	12.7	9.1
14	C	17.8	9.0
15	C	C	14.5
16	19.6	C	20.4
17	C	19.8	C
18	C	12.4	8.3
19	C	10.7	6.8
20	C	13.9	7.5
21	C	17.5	8.7
22	C	14.4	10.6
23	C	9.9	12.2
24	C	20.7	19.6
25	C	10.1	14.7
26	C	16.2	16.9
27	3.2	22.5	17.4
28	3.6	16.7	13.8
29	4.6	17.6	12.9
30	7.4	9.8	10.5
31	C	10.5	C
32	C	10.0	10.8
33	10.6	9.2	9.4
35	C	7.3	4.6
36	C	C	8.7
37	C	15.7	9.3
38	C	7.0	7.4
39	C	7.6	7.3
40	C	7.3	C
44	C	C	1.3
45	C	C	3.6
46	C	1.8	1.0

Summary, March Conditions

During the March 1990 period, winds are variable. For the period 10 to 13 March, winds are from the west. Openings in the ice appear in the west and across the center of the region. Motion vectors derived from the imagery are very short. Over the next 3 days, 13 to 16 March, there is some closing of open water in the east. Winds are from the south on 14 and 15 March and from the west on 16 March. The large scale shows ice moving toward Fram Strait. Winds on 17 March are from the east. Ice moves into the region from the northeast. Motion vectors indicate that everything is moving to the east for the period 13 to 16 March.

This period contains approximately 6% open water and there are no dominant lead directions. In fact, there are few long leads and many fractures. The ambient noise for this period is shown in Figure 51.

Table 38. Open-Water Fraction March 1990.

Block	Percent Open Water			
	10 Mar	13 Mar	16 Mar	17 Mar
1	C	C	3.9	2.9
2	C	C	12.1	7.9
3	C	C	3.7	C
4	C	C	1.8	C
5	C	2.4	4.0	4.7
6	C	2.3	3.2	3.2
7	C	1.1	3.5	C
8	C	3.3	C	2.5
9	C	C	4.4	C
10	5.1	C	3.7	C
11	3.8	3.6	5.9	C
12	0.4	C	1.2	C
13	2.8	3.9	3.2	3.1
14	4.2	2.7	C	4.4
15	C	2.8	C	2.5
16	C	1.4	C	C
17	1.7	C	7.2	C
18	0.7	5.7	4.8	C
19	6.4	7.1	C	3.2
20	3.8	C	4.3	3.5
21	2.3	1.8	2.3	2.2
22	4.7	4.1	C	7.7
23	6.3	3.9	C	6.0
24	8.1	C	C	5.2
25	C	8.1	9.8	C
26	3.4	8.9	11.6	10.5
27	4.6	C	13.5	11.7
28	5.9	C	11.4	11.2
29	9.6	11.4	C	12.6
30	3.9	4.3	C	5.3
31	7.9	7.4	3.6	5.7
32	11.8	C	C	10.3
33	4.4	7.2	C	C

Table 38. (con't.)

34	4.7	5.7	C	3.4
35	3.9	6.3	6.5	5.4
36	4.4	C	C	3.2
37	3.7	3.5	C	C
38	8.2	4.4	5.2	C
39	7.8	5.3	3.5	C
40	8.2	4.6	C	C
43	C	C	C	13.2
44	C	6.5	C	9.4
45	C	C	C	16.2
46	3.3	2.2	5.1	4.8
47	2.5	1.9	2.0	3.5

Correlations Between Ambient Noise and Open-Water Fraction

During each of the 4 periods selected for this analysis, daily measures of ambient noise were compared with open-water fraction. The time periods that are analyzed in this technical note are shown for each frequency in figures 52, 53, and 54.

In order to study the correlation between daily measured ambient noise and open water fractions determined from NOAA AVHRR imagery, the correlation coefficient was computed for a number of sets of data. The Pearson-Product Moment method was used to determine the correlation coefficients. The results are presented in Tables 39, 40, and 41 (* indicates significance at the error level given in parentheses).

Table 39. Correlation Coefficients for Ambient Noise and Open-Water Fractions by Frequency.

Frequency	r (all cases)	r (omit January case)
15 Hz	-0.24	-0.56 * (5%)
50 Hz	0.29	-0.59 * (2.5%)
250 Hz	-0.01	-0.56 * (5%)

Table 40. Correlation Coefficients for Ambient Noise and Open-Water Fractions by Case.

Case	r
Early December	-0.48 * (10%)
Late December	-0.60 * (2.5%)
January	0.70 * (2.5%)
March	-0.45 * (10%)

Table 41. Correlation Coefficients for Ambient Noise and Open-Water Fractions by Event and Frequency.

Event and Frequency		r
ED	15 Hz	-0.65
ED	50 Hz	-0.82
ED	250 Hz	-0.98 * (10%)
LD	15 Hz	-0.69

Table 41.(con't)

LD	50 Hz	-0.98 * (1%)
LD	250 Hz	-0.85 * (10%)
JA	15 Hz	0.87
JA	50 Hz	0.80
JA	250 Hz	0.92
MA	15 Hz	0.42
MA	50 Hz	-0.82 * (10%)
MA	250 Hz	-0.9975 * (0.5%)

Table 42. Statistics for Noise and Percent Ice Coverage for Early December.

	Frequency			Blocks						
	15	50	250	19	21	22	29	X	all	common
AVE.	88.67	80.67	76.00	96.00	96.83	96.07	97.23		96.17	96.53
SD	5.91	4.64	2.82	1.71	2.18	1.41	1.27		1.54	1.60
RANG	13.00	11.00	6.00	3.90	5.00	3.20	3.10		3.40	3.70

Table 43. Statistics for Noise and Percent Ice Coverage for Late December.

	Frequency			Blocks						
	15	50	250	8	16	22	23	30	all	common
AVE.	85.25	78.50	76.50	90.60	91.15	93.35	92.83	95.83	95.28	93.85
SD	2.38	3.50	6.22	4.84	3.16	2.40	5.90	3.87	1.61	2.02
RANG	6.00	9.00	16.00	13.20	6.70	5.7	2.37	10.00	4.10	5.40

Table 44. Statistics for Noise and Percent Ice Coverage for January.

	Frequency			Blocks						
	15	50	250	27	28	29	30	33	all	common
AVE.	82.33	83.00	73.00	85.63	88.63	88.30	90.77	90.27	89.20	88.70
SD	4.19	7.87	7.87	8.17	5.62	5.37	1.33	0.62	0.71	3.94
RANG	10.00	18.00	18.00	19.30	13.10	13.00	3.10	1.40	1.60	9.30

Table 45. Statistics for Noise and Percent Ice Coverage for March.

	Frequency			Blocks						
	15	50	250	13	21	26	31	35	all	common
AVE.	83.75	72.00	70.50	96.75	97.85	91.40	93.85	94.73	94.65	94.85
SD	1.30	5.10	6.73	0.40	0.21	3.15	1.68	1.14	0.67	0.62
RANG	3.00	14.00	17.00	1.10	0.50	8.20	4.30	2.60	1.80	1.60

The 15 Hz daily ambient noise levels are highest in early December and decrease through March, as shown in Figure 52. The amount of open water increases for the period,

early December through January, suggesting that the decrease in ambient noise levels may be related to the amount of open water present. Studying the individual cases indicates that the ambient noise level follows the general shape of the curve describing the amount of ice cover present for the December cases. The relationship is not exact as shown in the first two points of the early December case and the second and third points of the late December case. For the January case, the relationship between the ambient noise level and the percent ice cover is inverse. High ambient noise levels are related to more open water. The March noise level is comparable to the levels maintained during late December and January and indicates quite a lot of variability. The amount of ice cover for the common blocks shows a slight opening of the area over the first 3 days and then it remains constant. The amount of open water for this March period is comparable to the amount of open water found during December.

The 50 Hz daily ambient noise levels and percent ice coverage for early and late December, January, and March 1990 are presented in Figure 53. The noise levels are 5 (for late December and January) to 15 dB (for early December) lower than the noise recorded at 15 Hz for the same time periods. The shapes of the ambient noise curves for early and late December and January mimic those at 15 Hz, but the variability is larger. This is especially true for the noise levels during January. Unlike the 15 Hz noise levels, where the December noise levels are higher than January, the January noise levels are higher than the December noise levels at 50 Hz, indicating more noise generated at 50 Hz for the case with more open water. The 50 Hz ambient noise levels for March are lower than the values recorded at that frequency for the December and January periods. The ambient noise curve indicates no relationship to the amount of open water in common blocks for the March period.

The measured daily ambient noise levels at 250 Hz and the percent ice for common blocks in the image for each day are presented in Figure 54. Values of ambient noise at 250 Hz are lower than values at 15 and 50 Hz for all cases. The average 250 Hz noise levels for the three periods are of the same order of magnitude, but the amount of variability from day to day increases from early December to January. The amount of open water increases from the first time period to the last and its variability increases also. The percent of ice coverage shows a positive correlation to the change in ambient noise level during early and late December. That is, as the amount of ice increases, or the amount of open water decreases, the level of ambient noise increases. The correlation does not hold for the January case. The relationship is inverse for the first 2 days of the January period, then the pattern is re-established. During the early portion of the January case, the noise increases dramatically, approximately 15 dB, as the amount of ice decreases (or the amount of open water increases). During March, the amount of ice coverage changes little, while the 250 Hz daily noise level decreases sharply, then rises slowly. The amount of ice present is higher than the late December and January cases and the variability is high.

4. CONCLUSIONS

Ambient noise at several frequencies is being generated. The level of noise differs with time and whether the amount of ice is increasing or decreasing. The variability also differs with frequency, time, and amount of ice present. When ice is compacted, the amount of noise is proportional to the amount of open water present and how that changes from one time period to another. Compacted ice is prevalent during the midwinter period (December) and during a wind that blows from offshore (northerly). Ambient noise levels may also be large. Some patterns that relate ambient noise and open water appear to exist. The most interesting of these is the fact that for open water values less than 8 to 10%, noise increases as the amount of open water decreases. For open water greater than 8 to 10%, noise increases as the amount of open water increases. Four samples are far short of the required number to state definitive correlations, but they do point to potentially interesting and useful means of determining changes in ambient noise level by monitoring open-water trends in the Arctic. The advent of SAR for cloud-free imagery will aid future analysis.

5. REFERENCES

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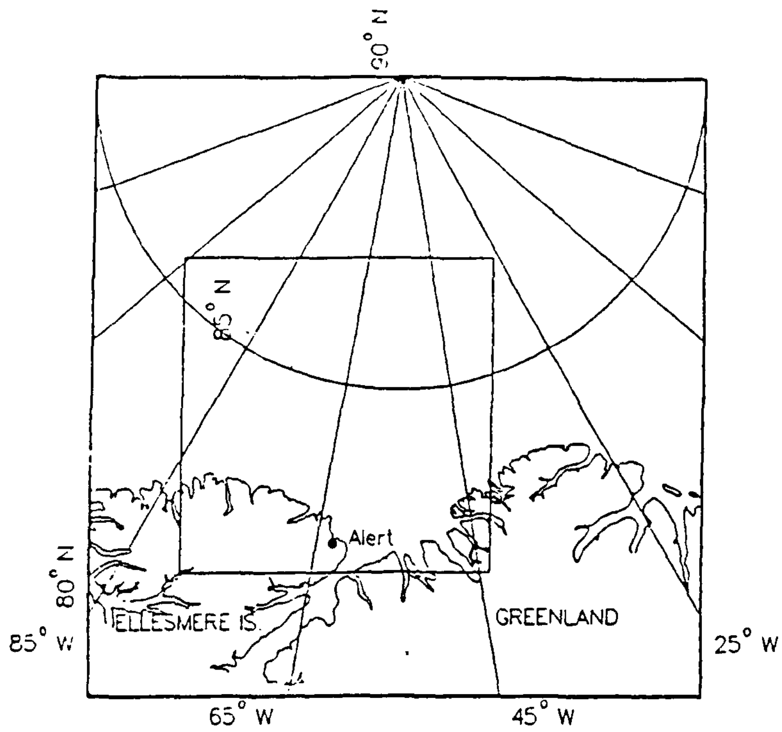


Figure 1. Area over which Imagery was acquired.

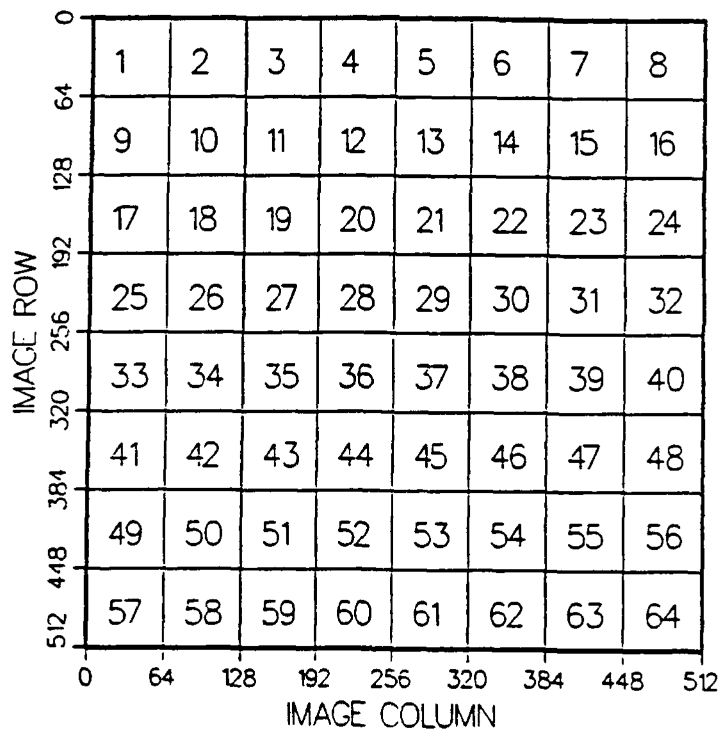
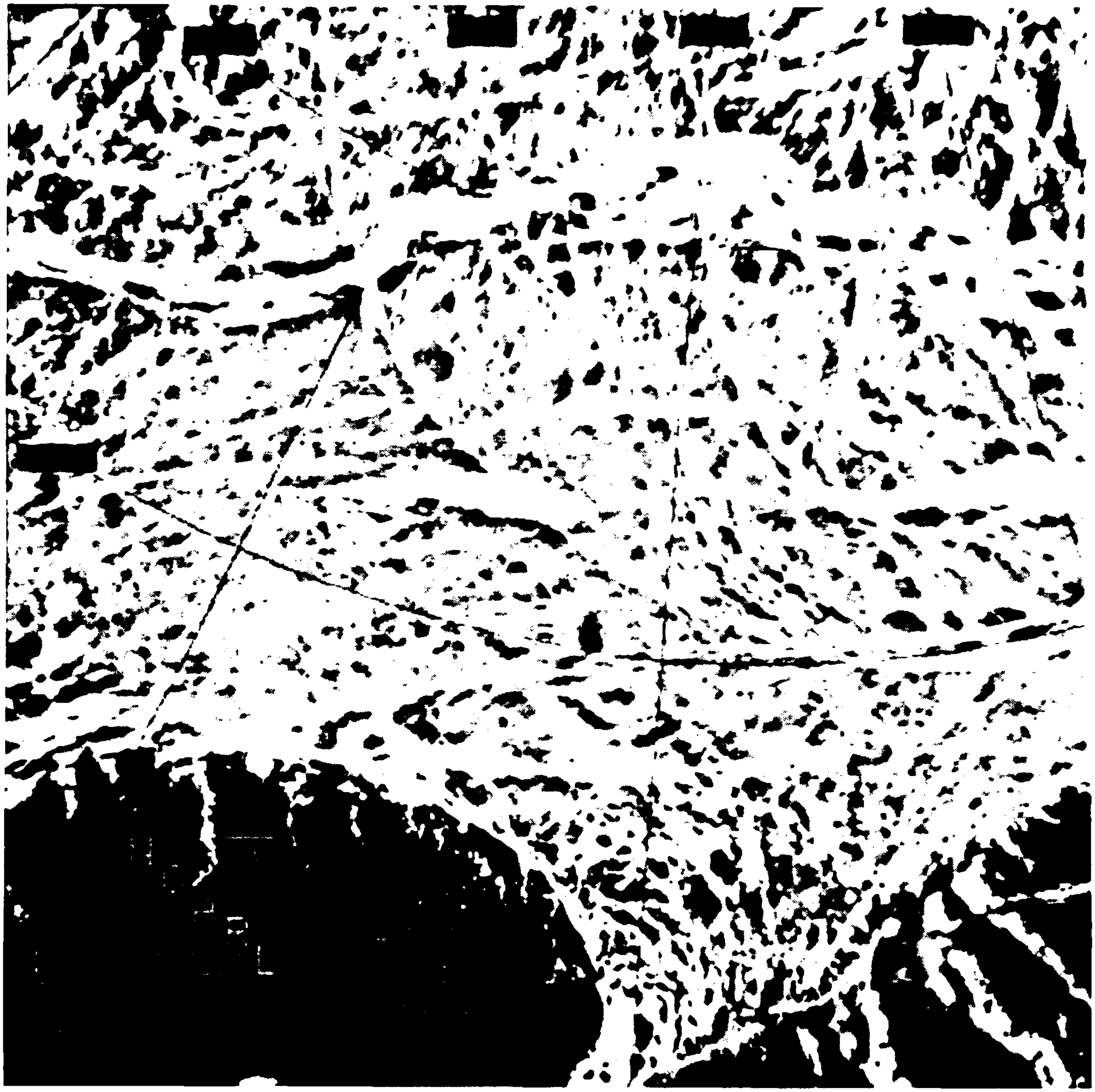
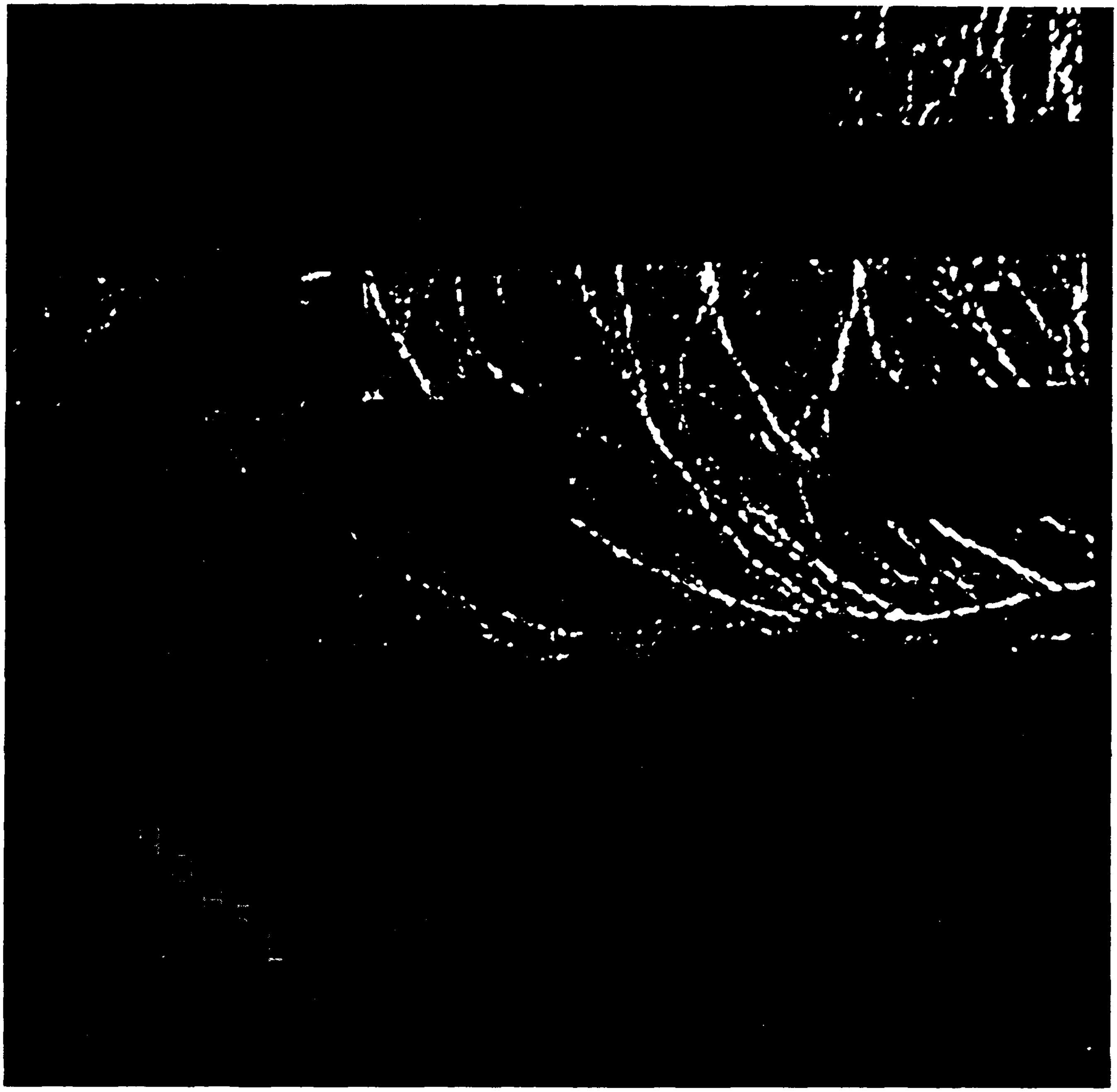
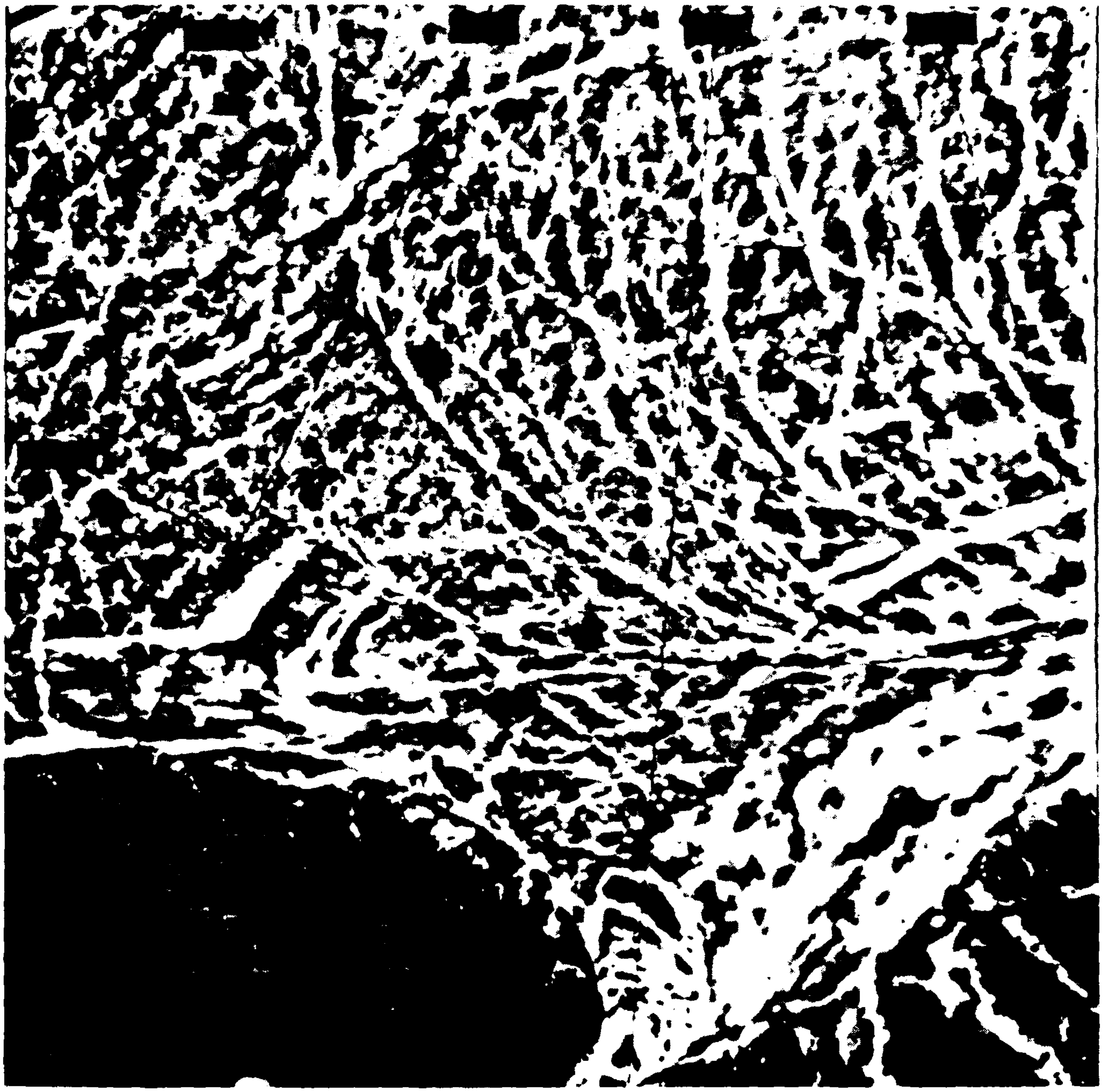
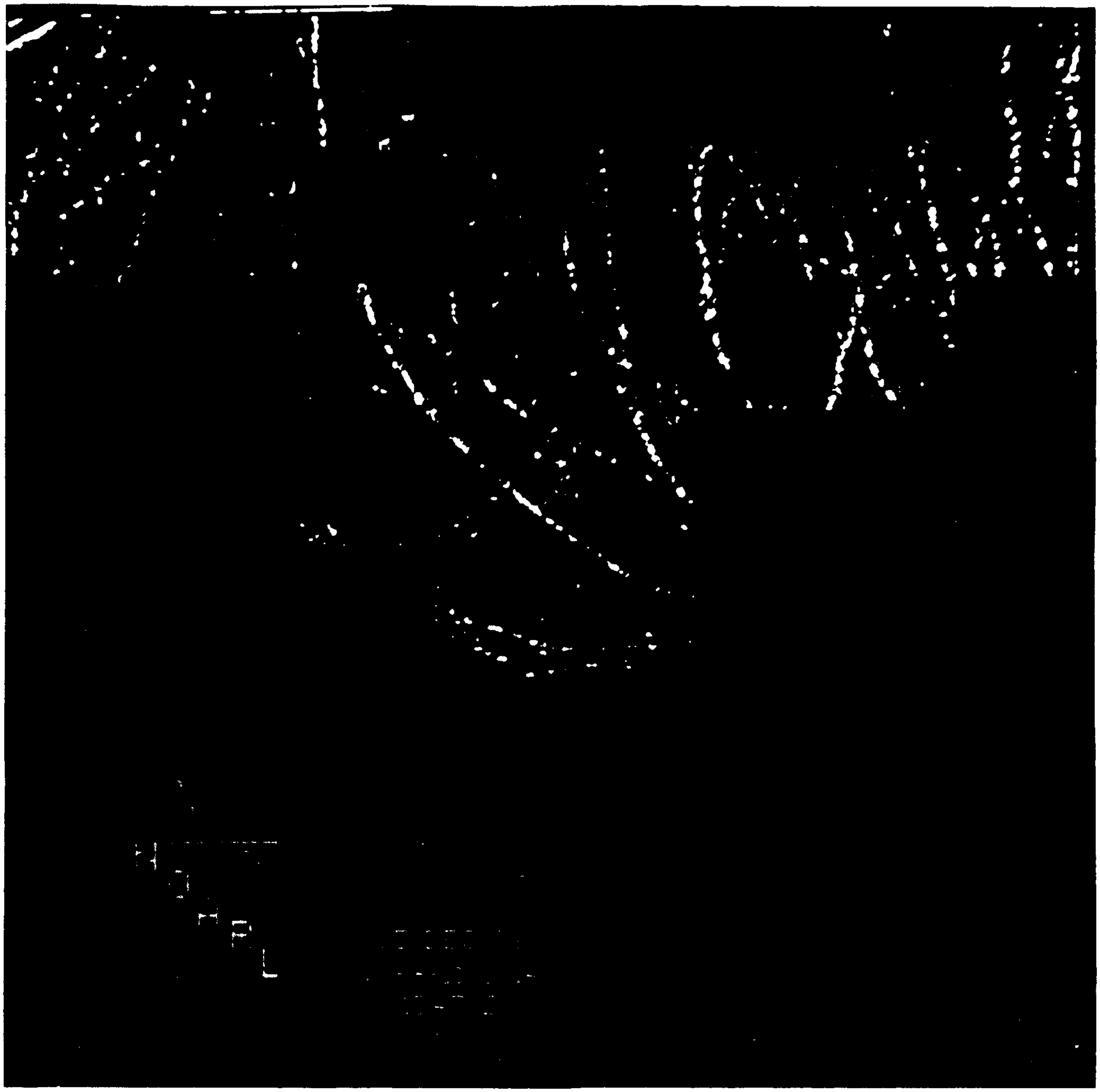


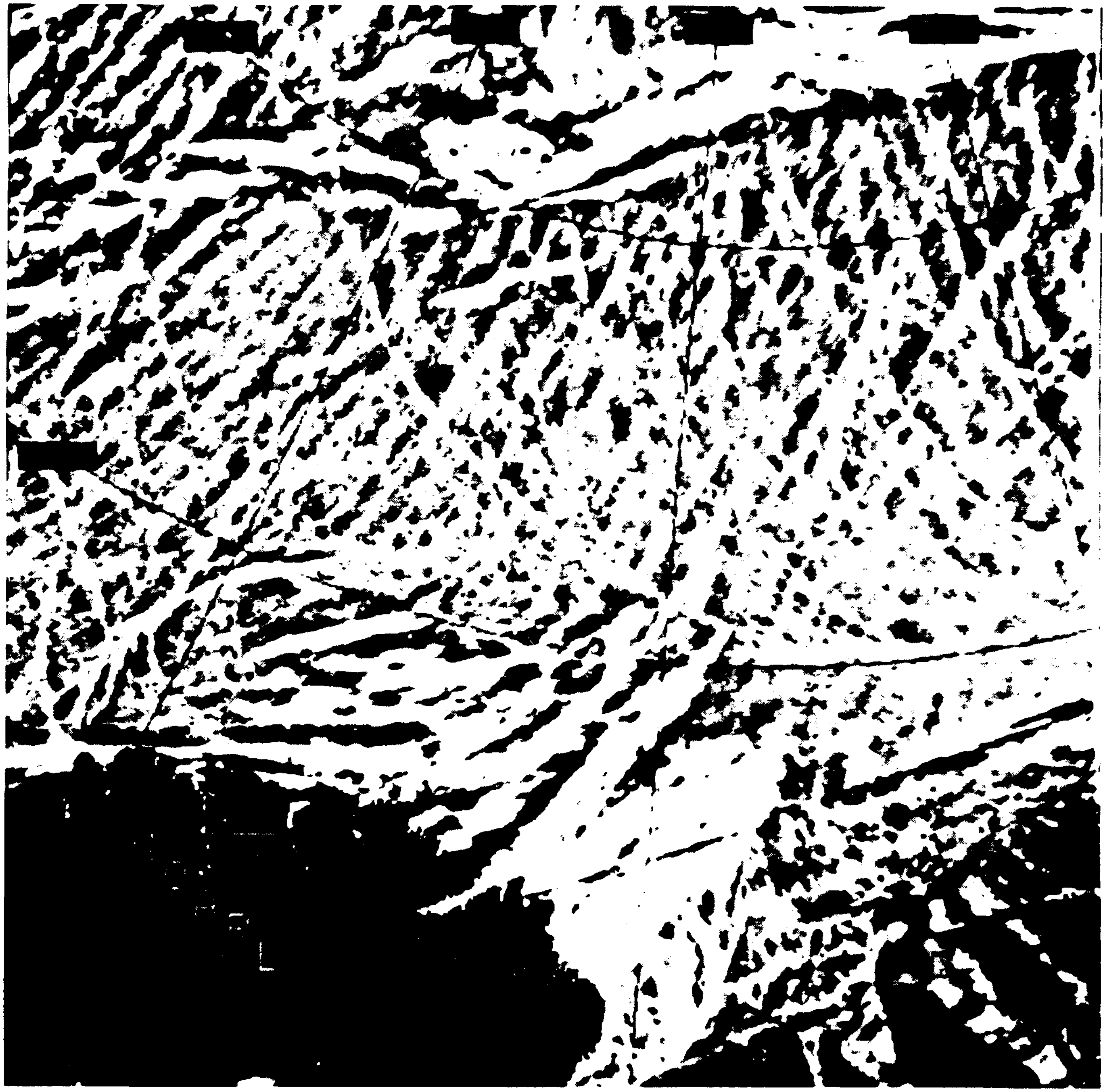
Figure 2. Image Grid Blocks used for Cloud Removal, Lead Orientation, and Open-Water Fraction.

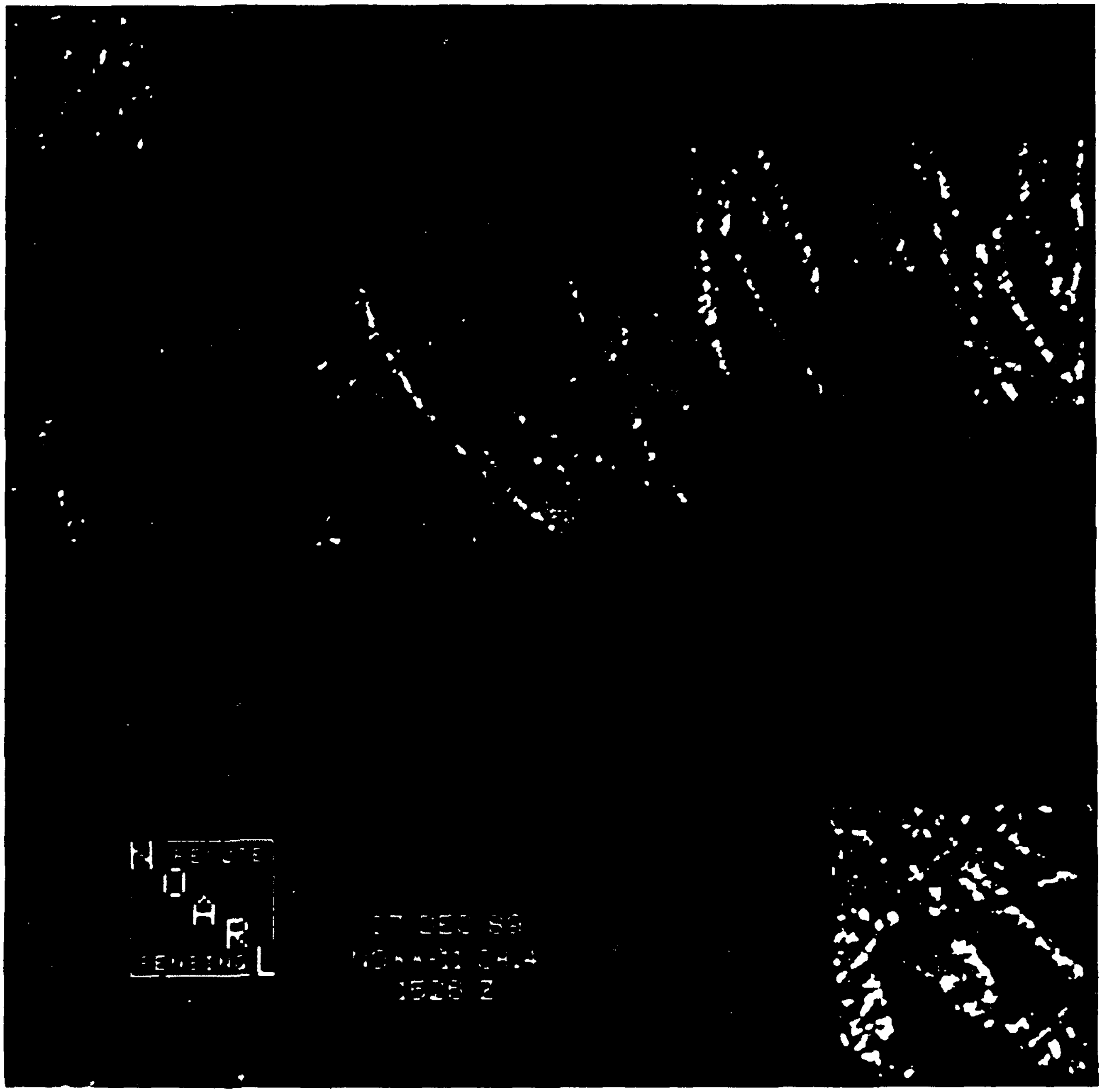








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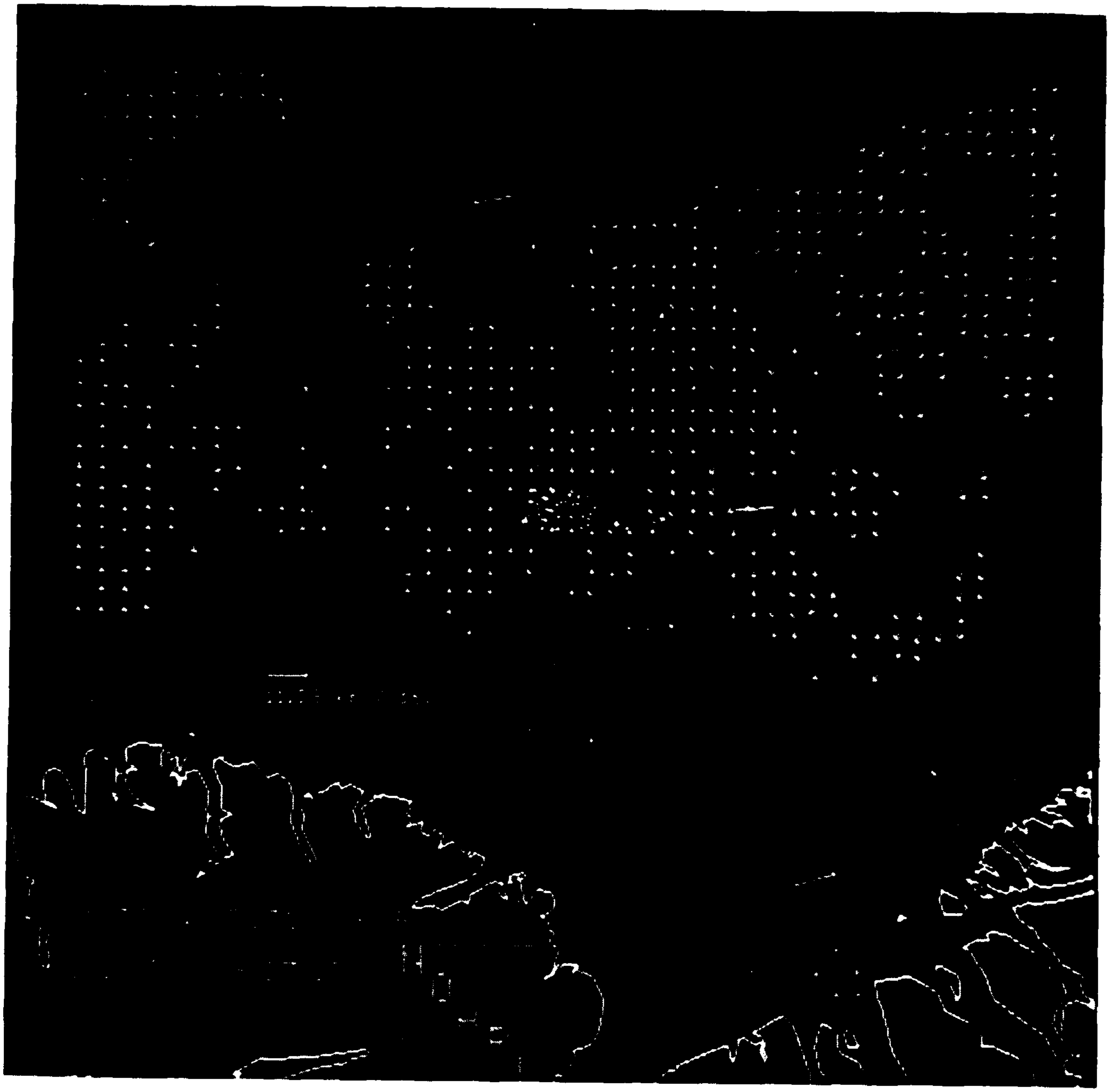

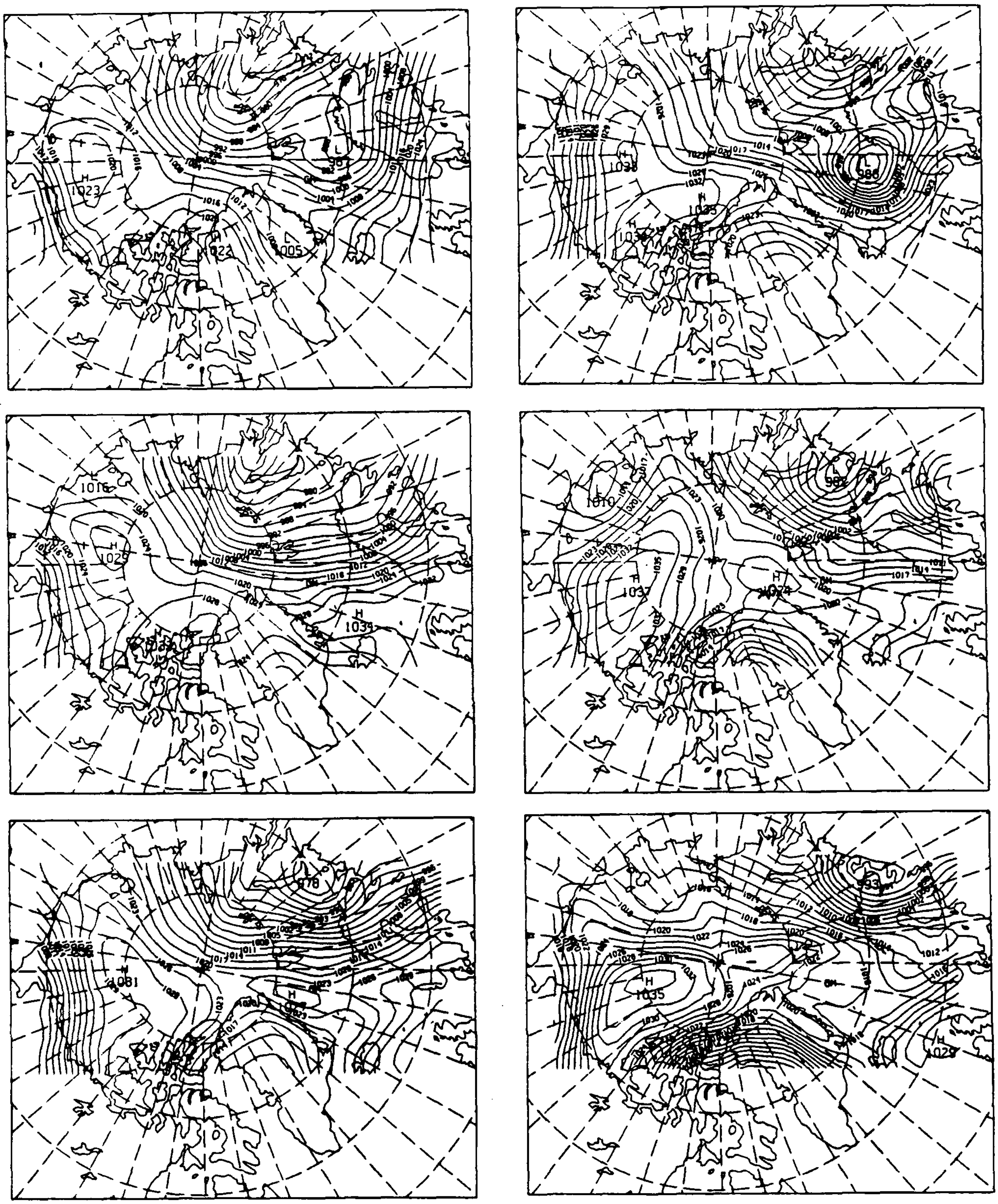

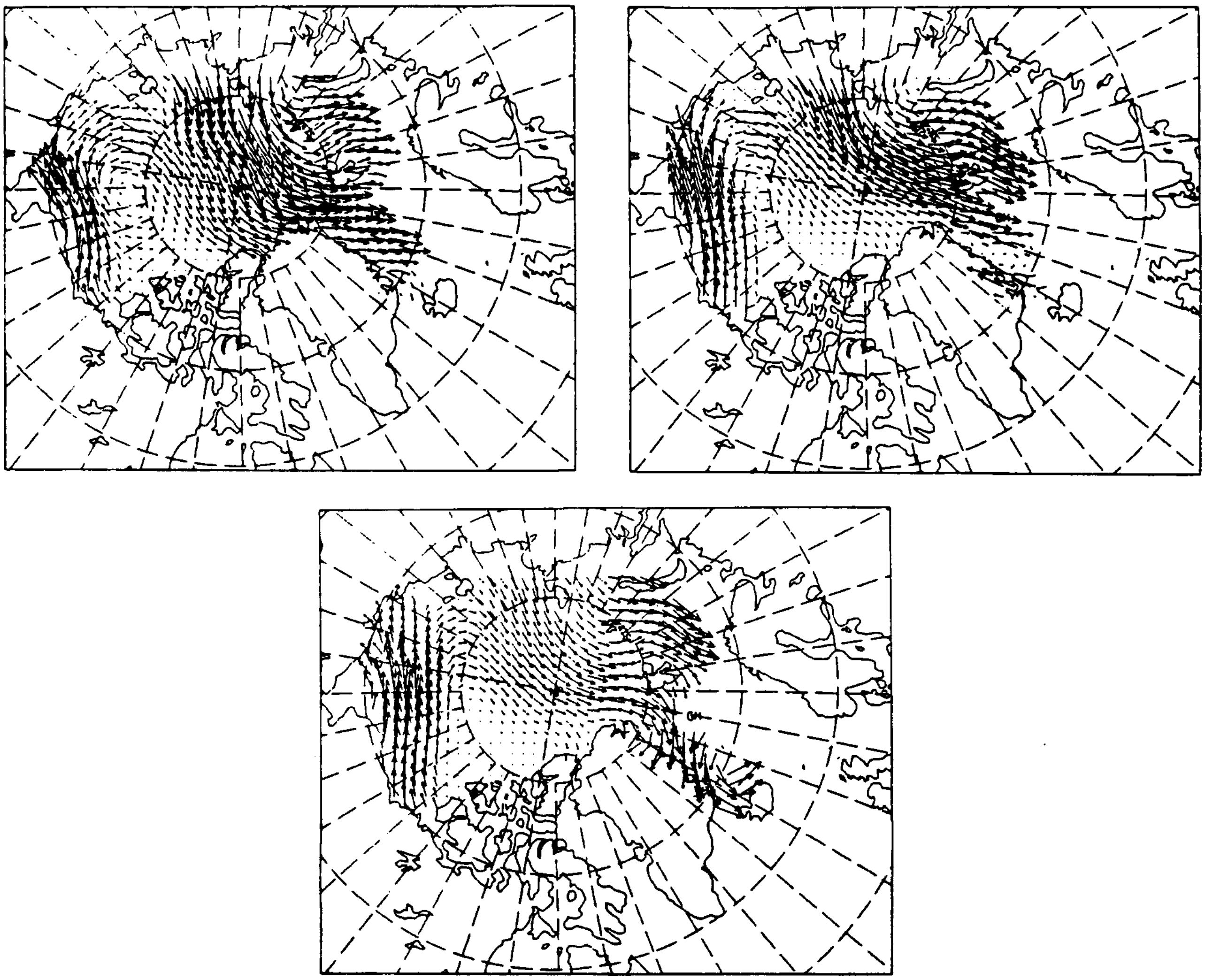

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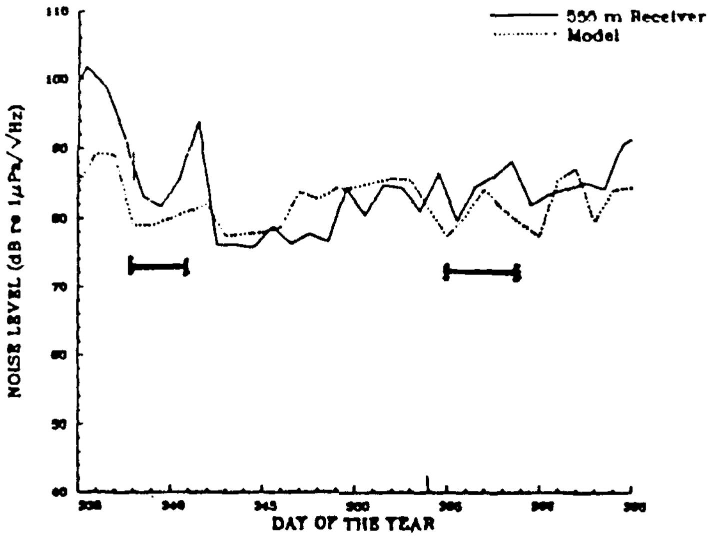

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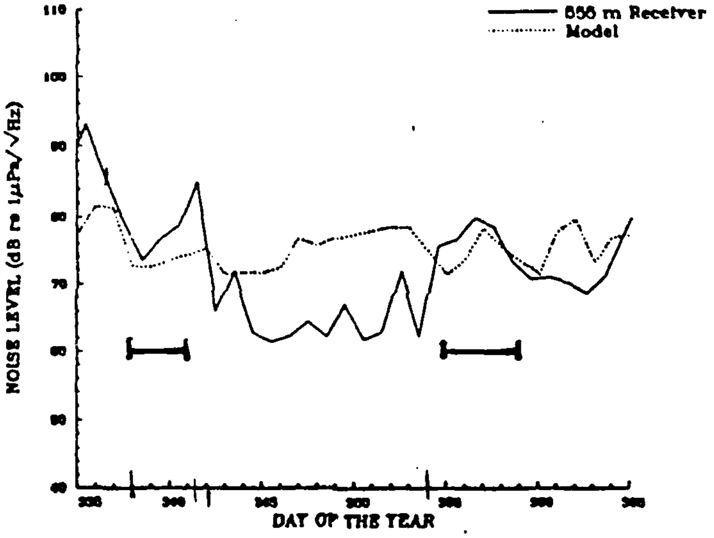

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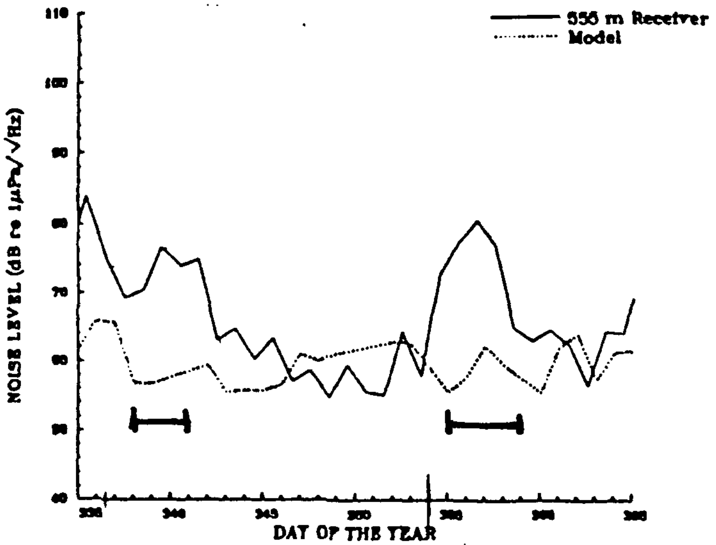

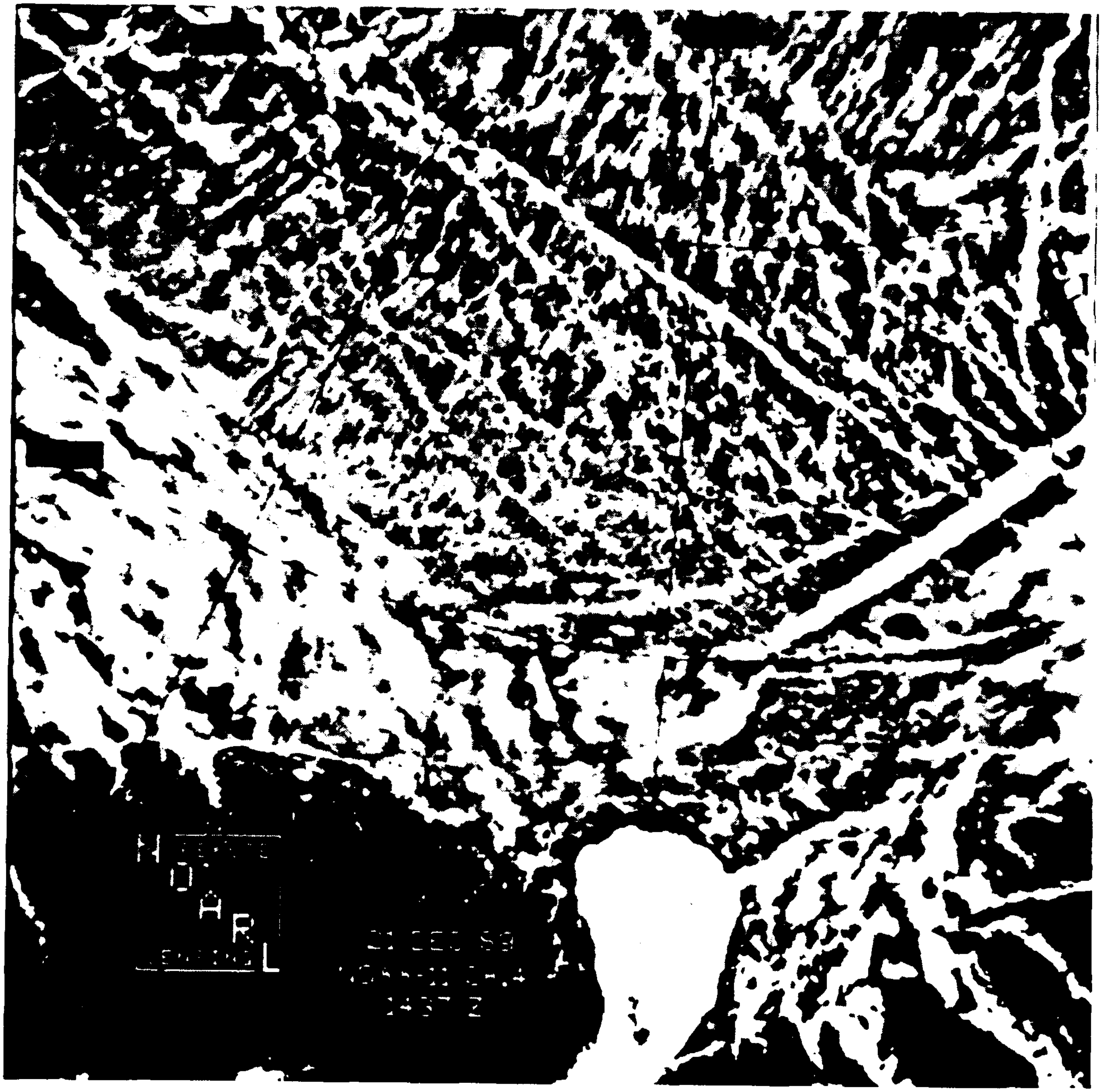
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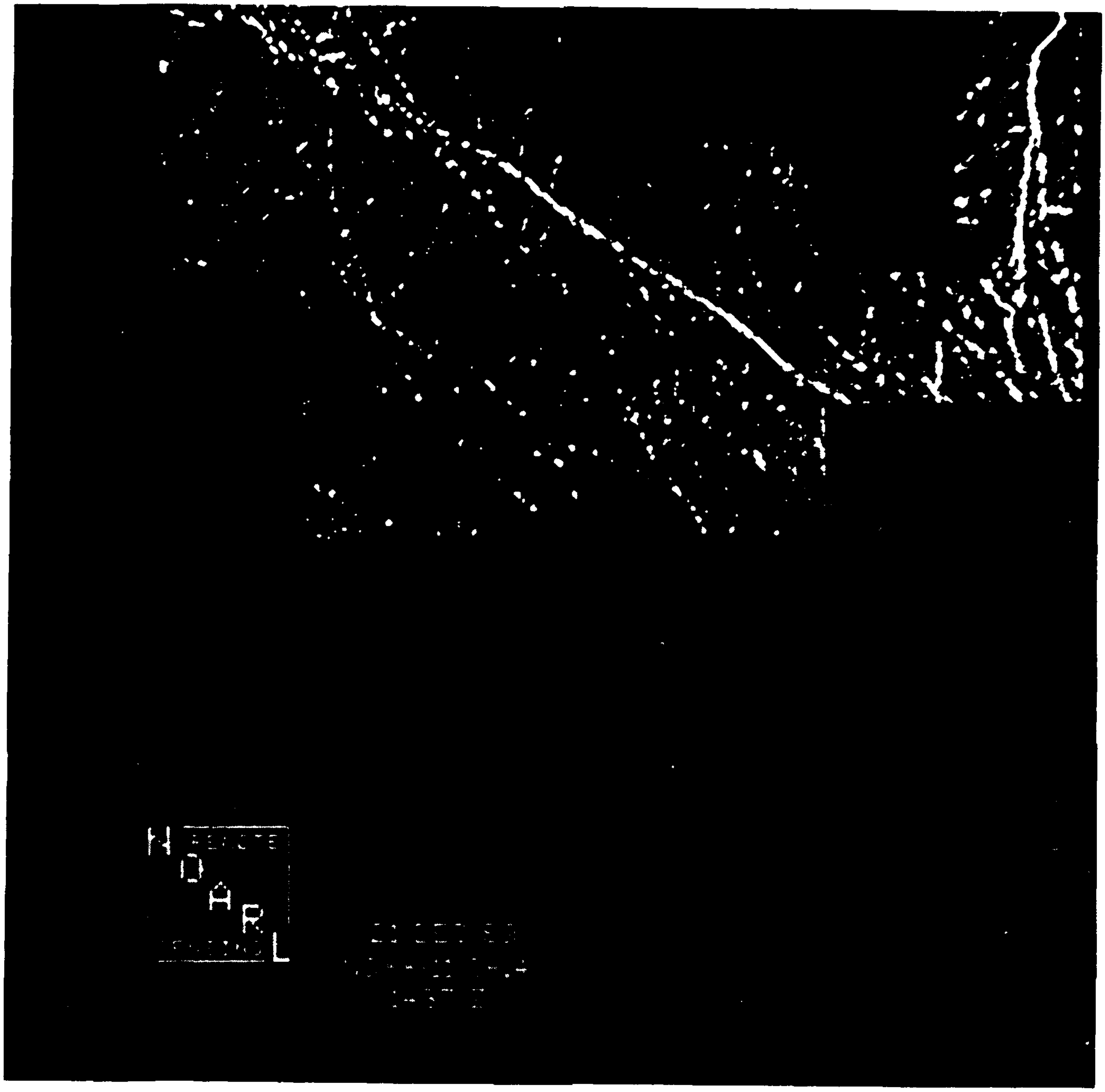

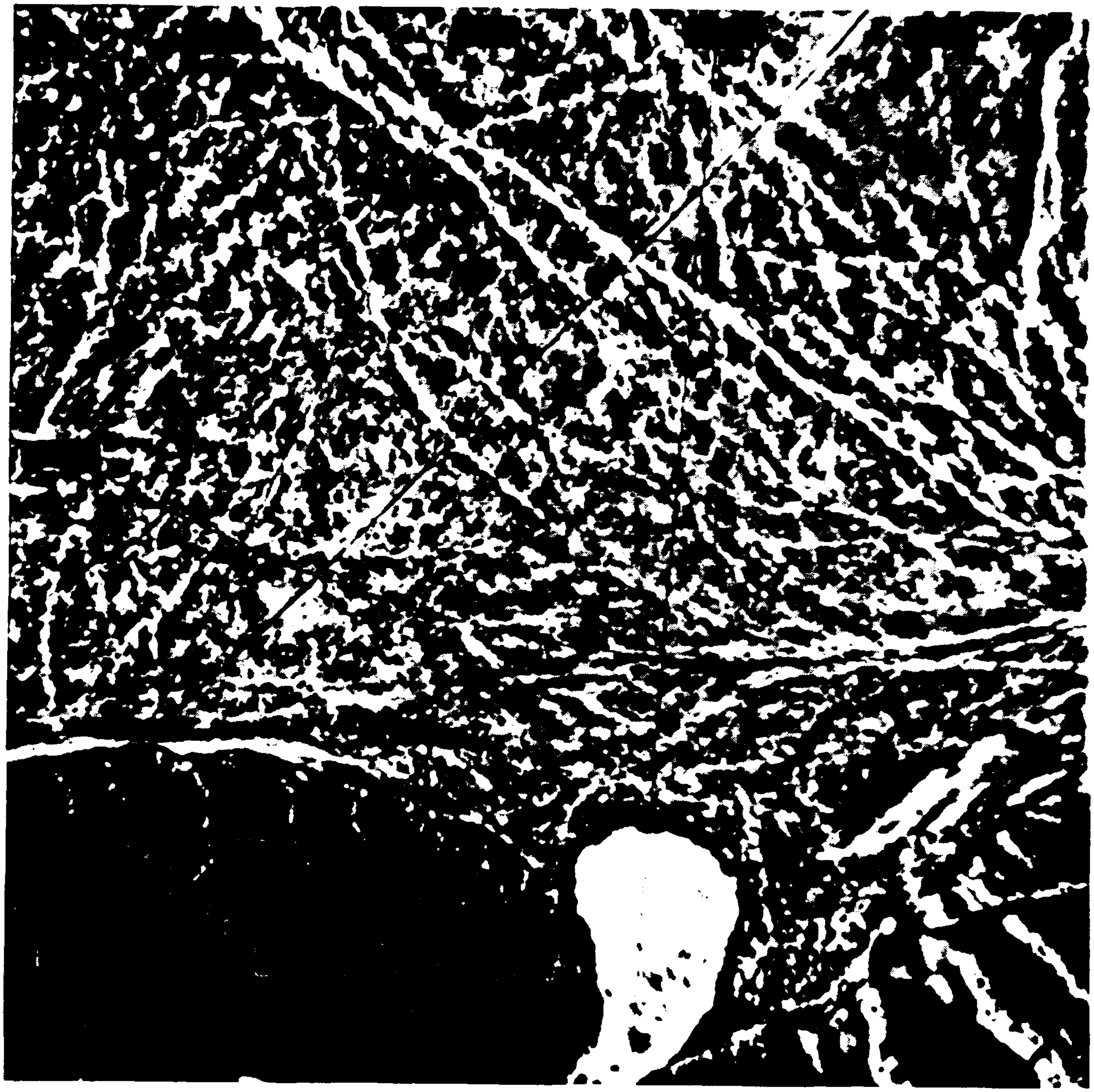

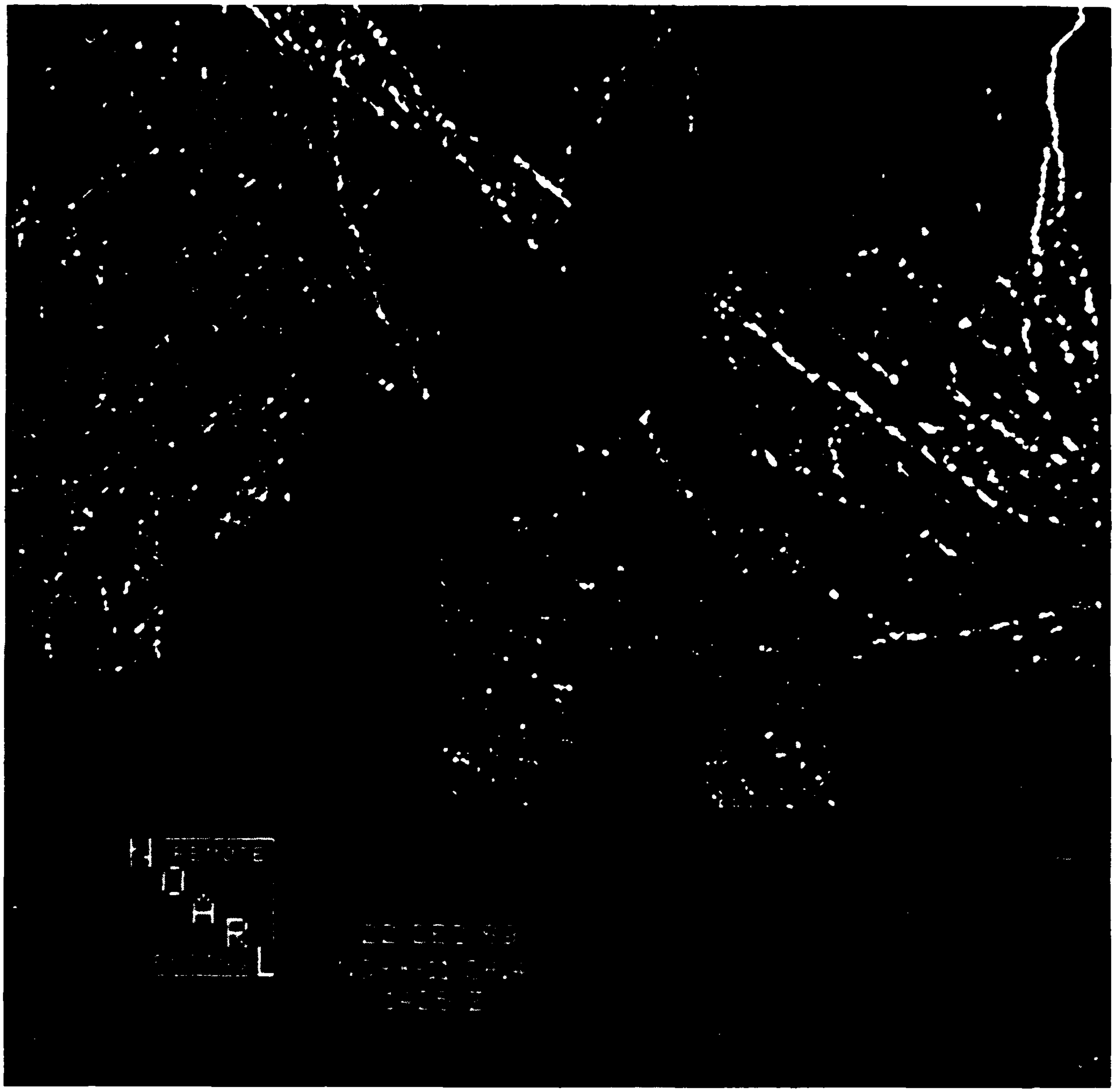

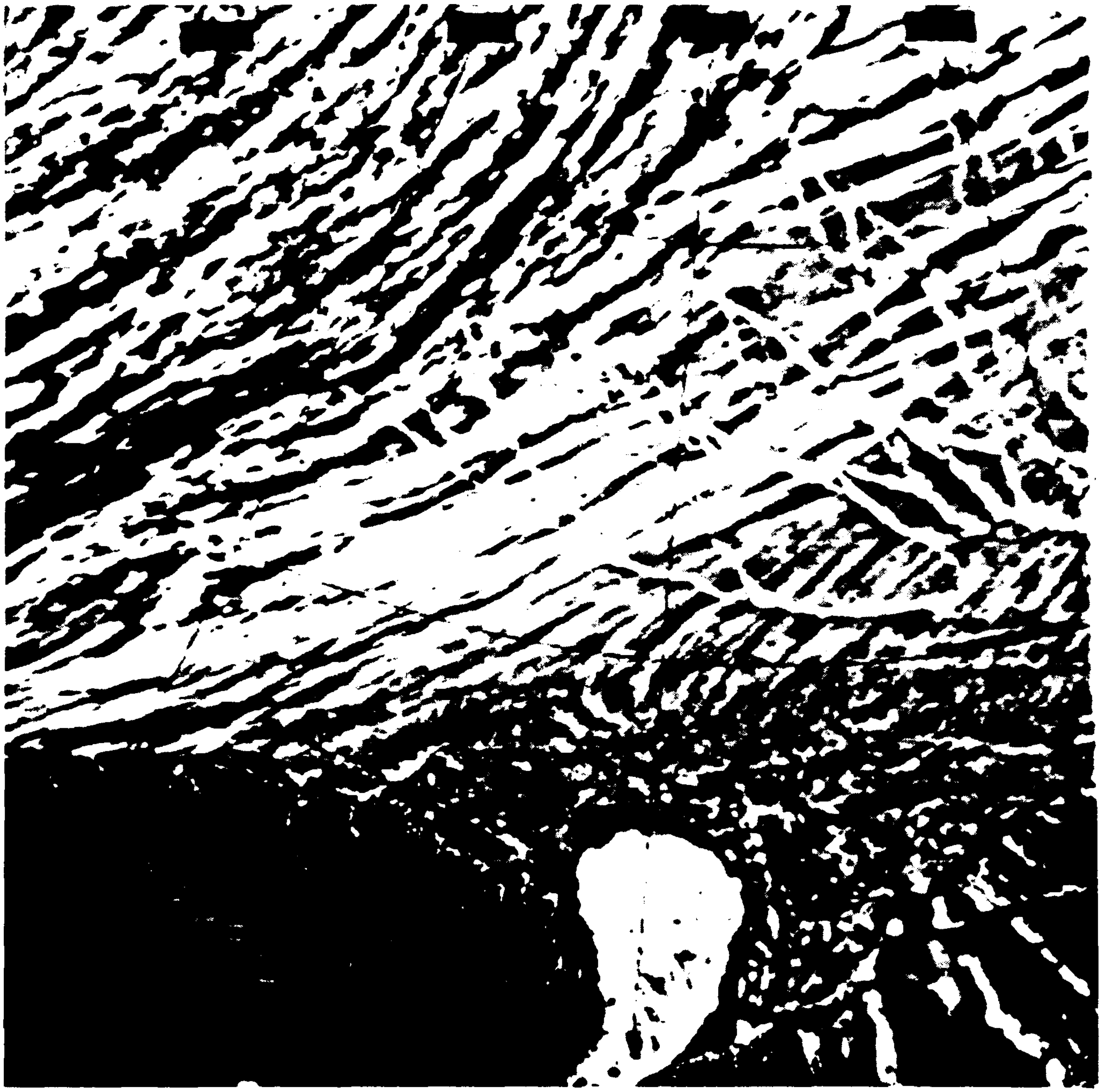

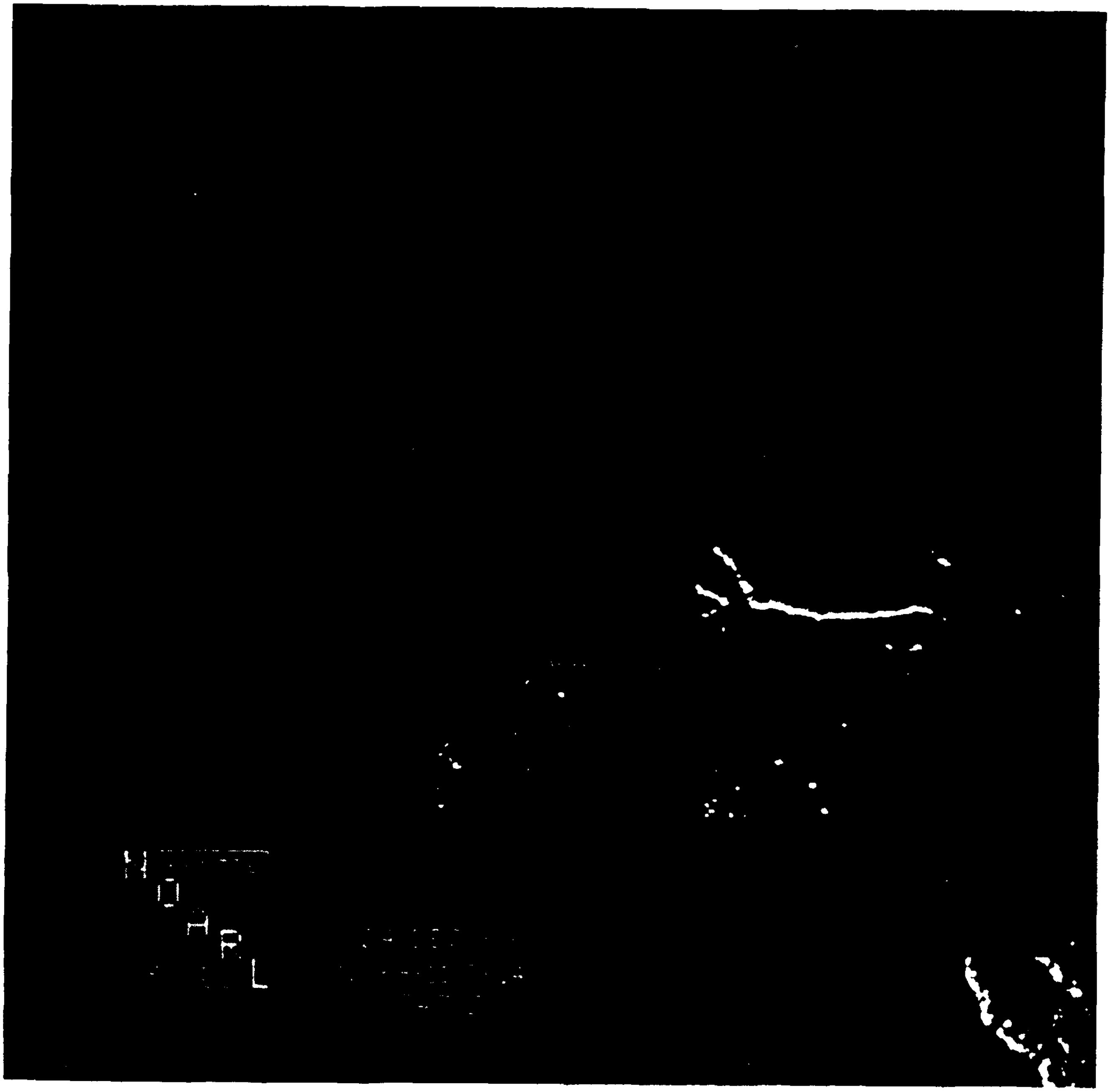

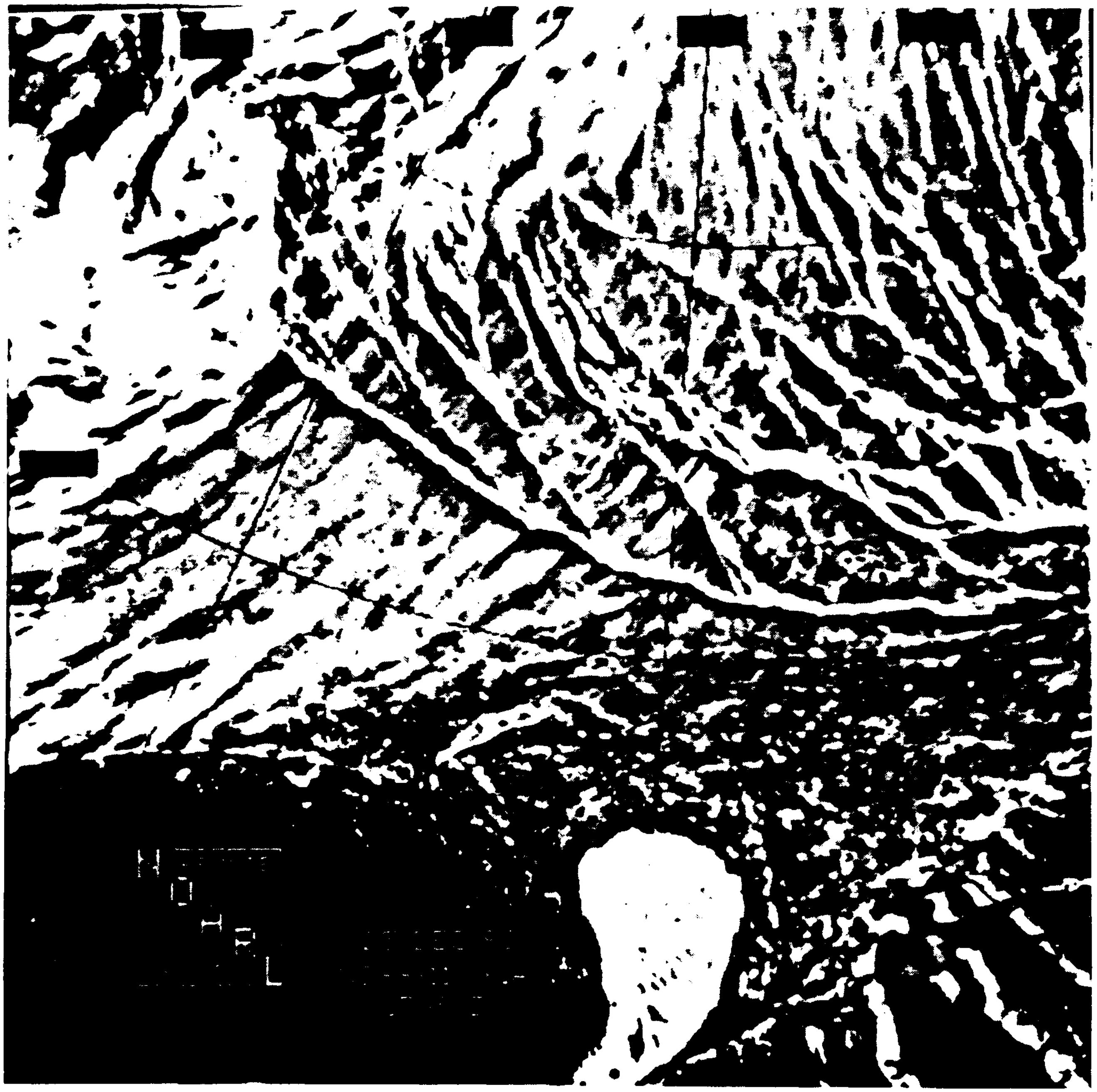


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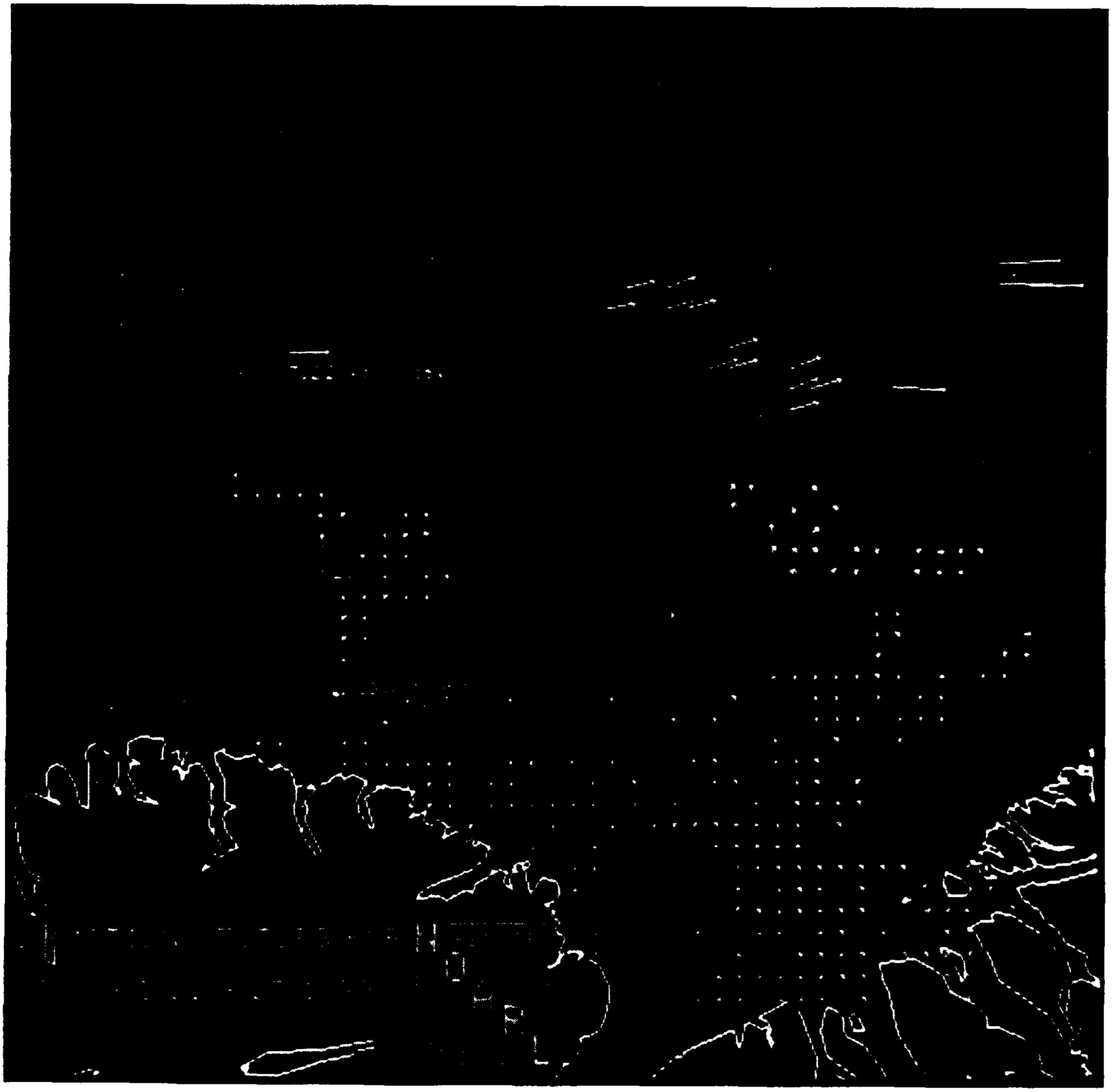

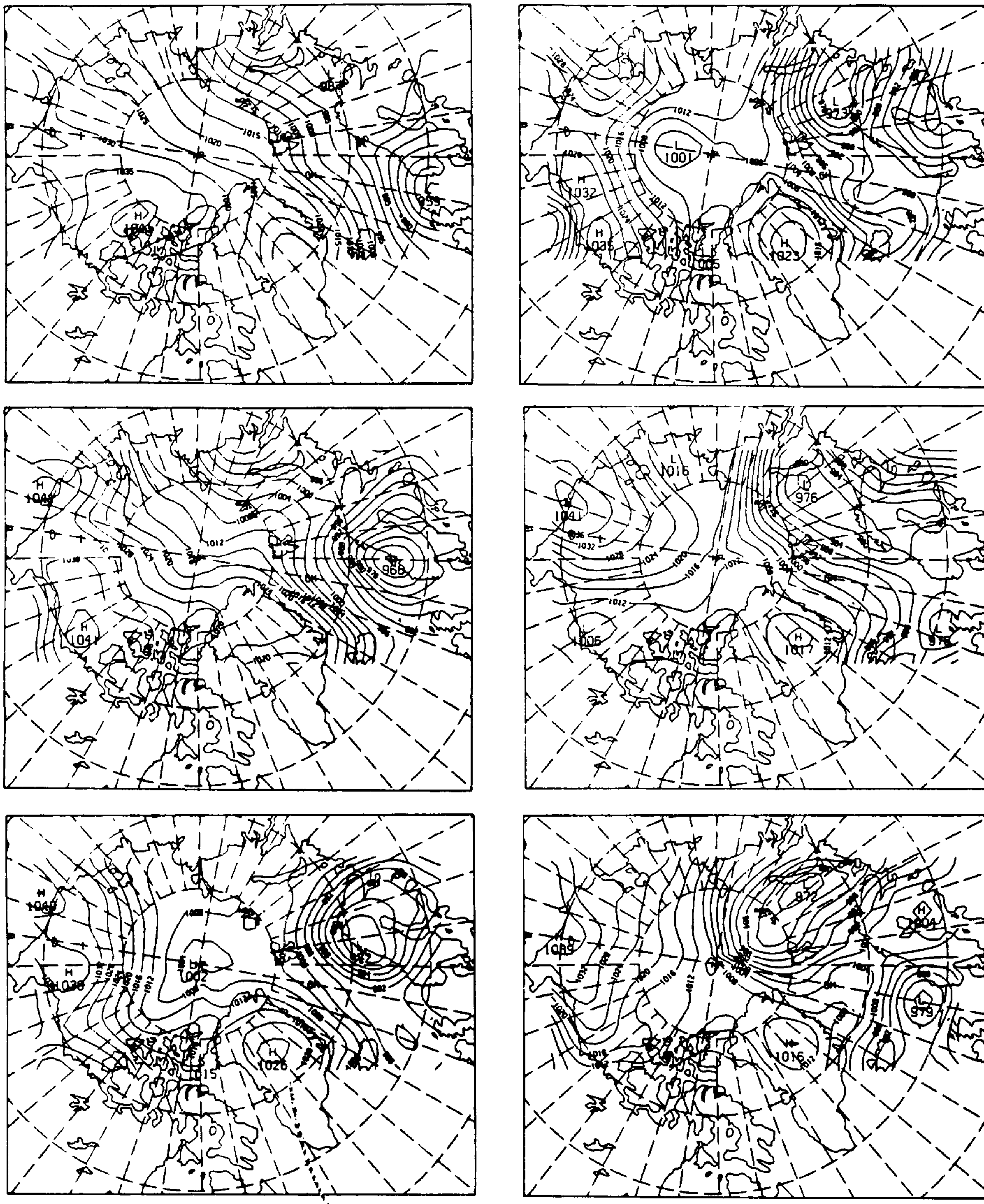

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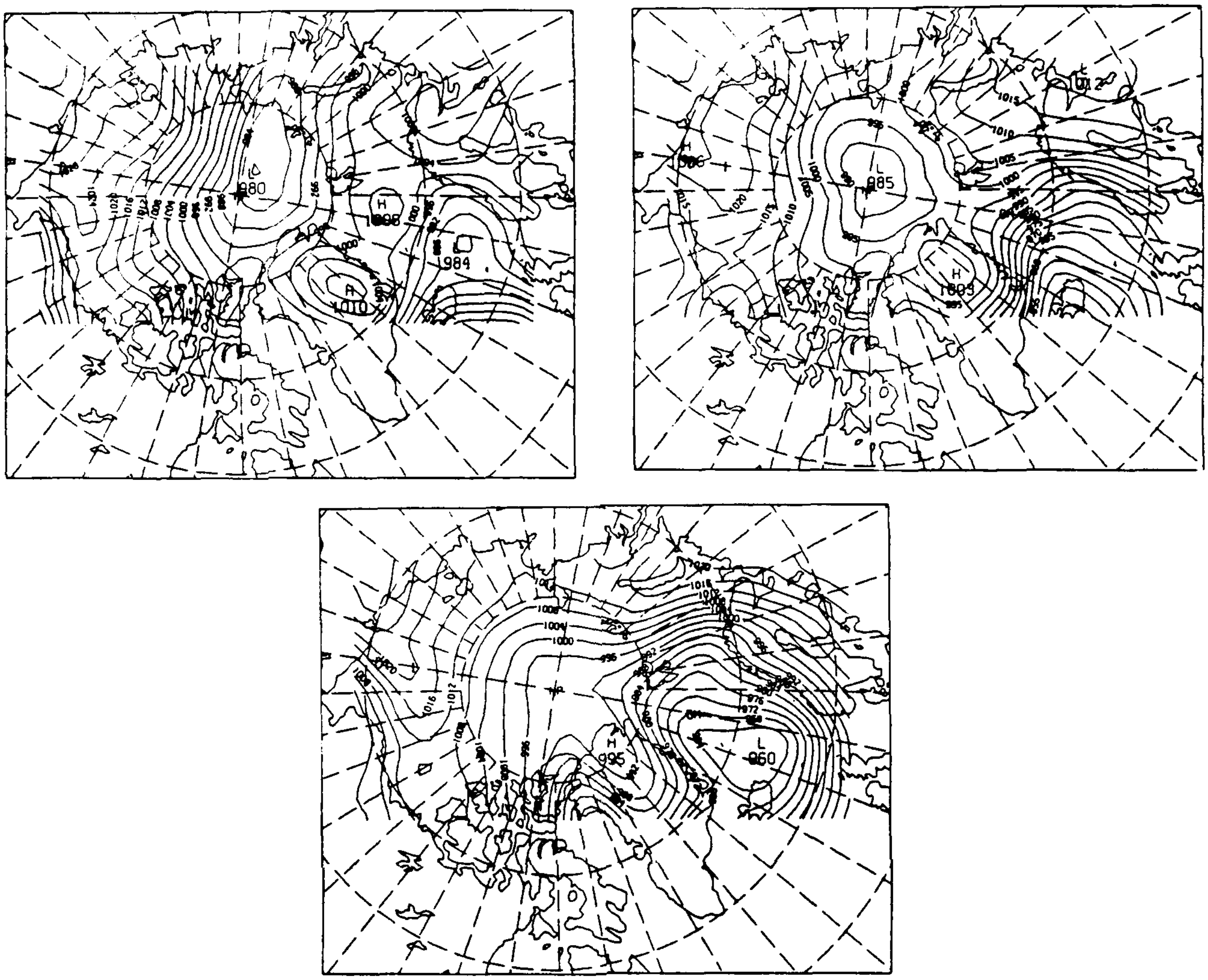

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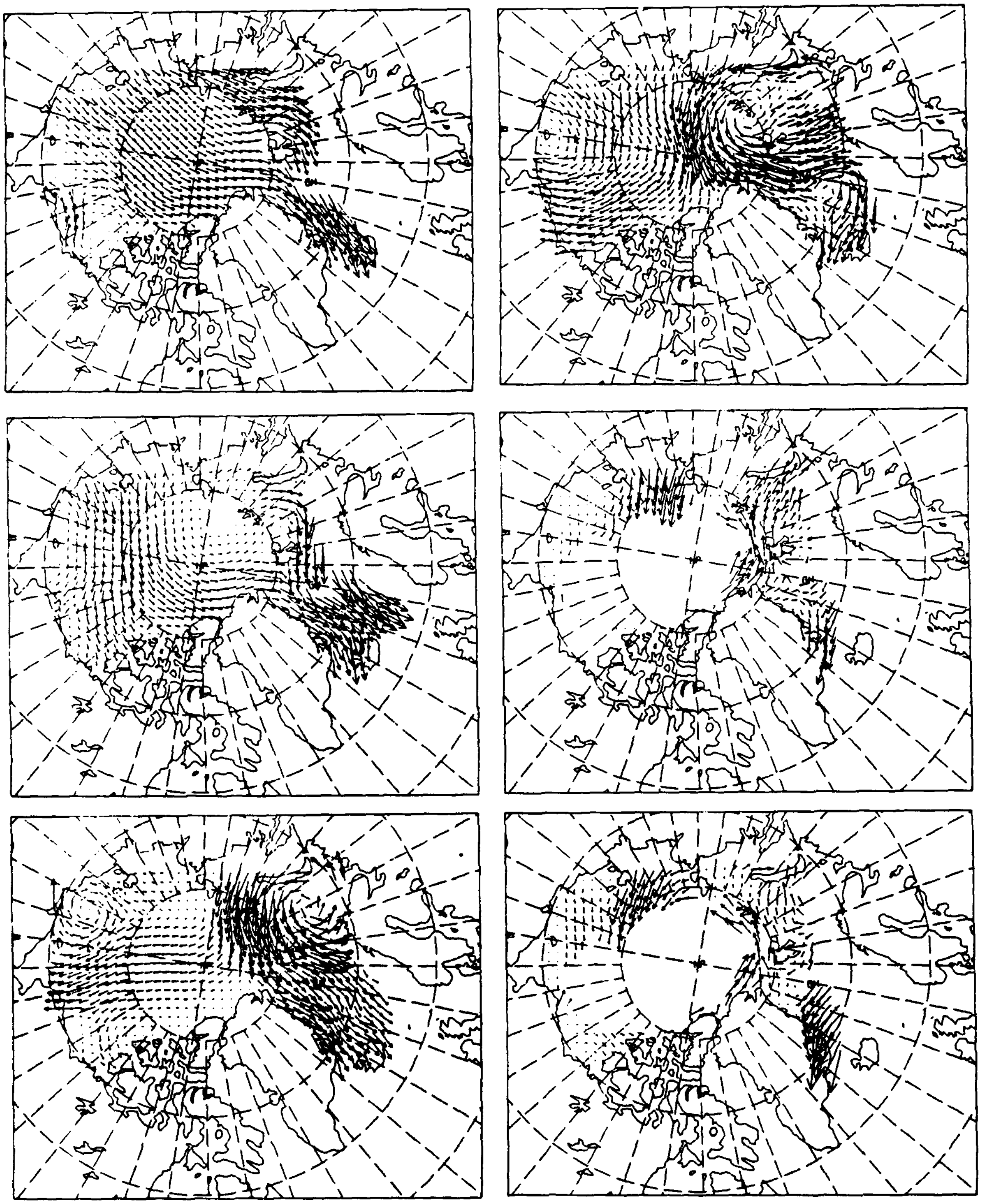
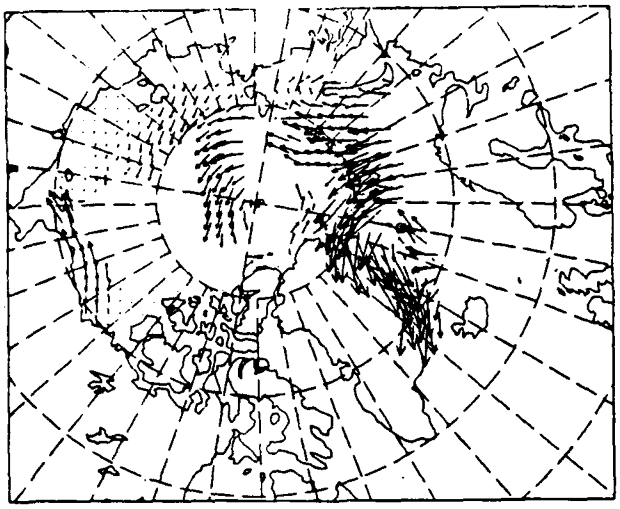
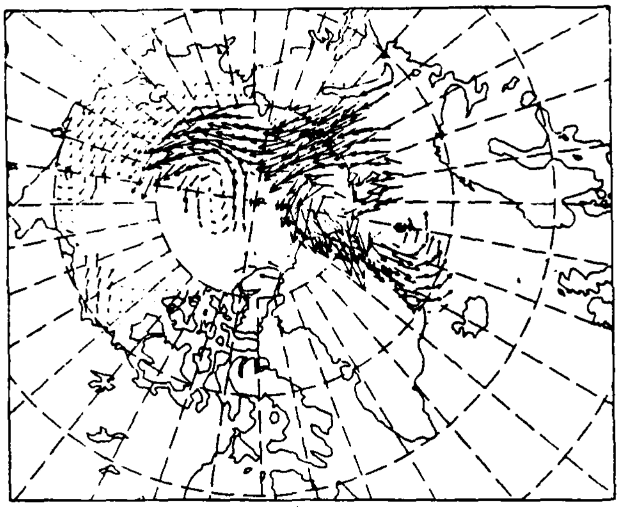
H 1010
L 984
L 985
H 1009
H 995
L 960







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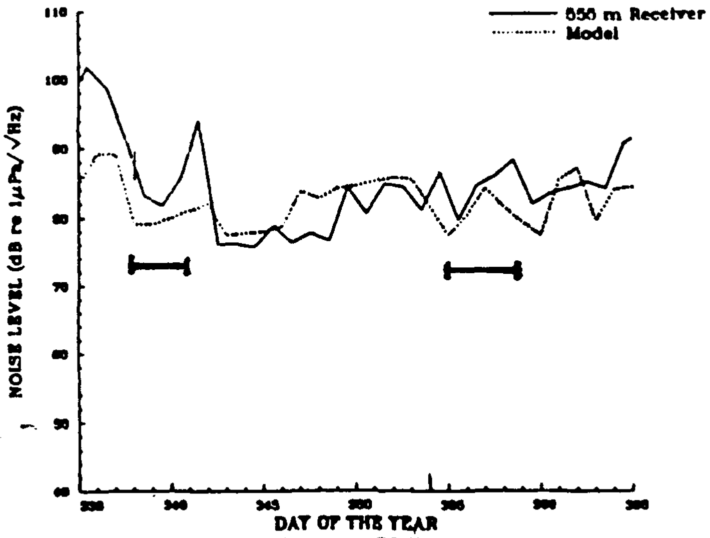

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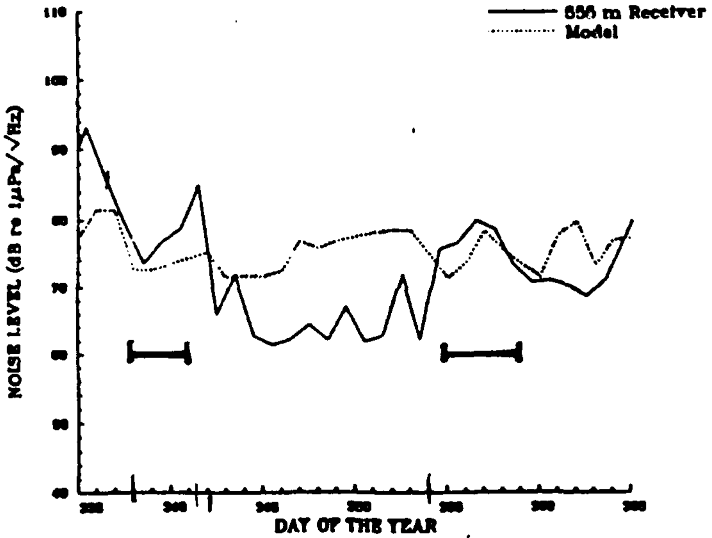
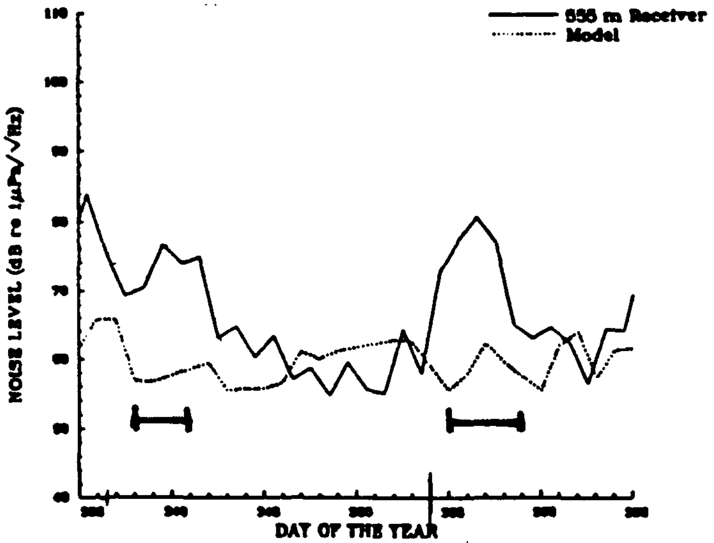
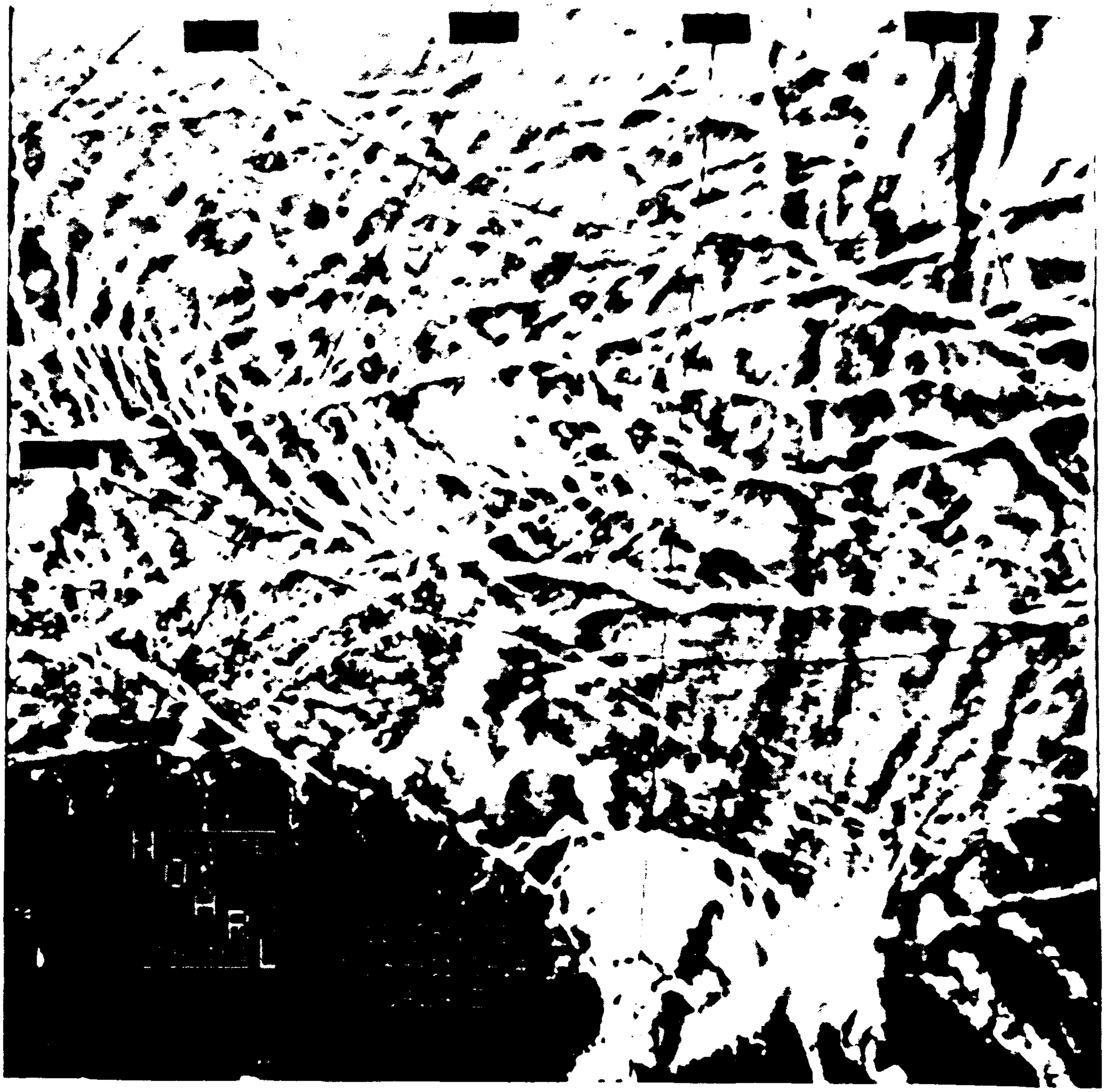
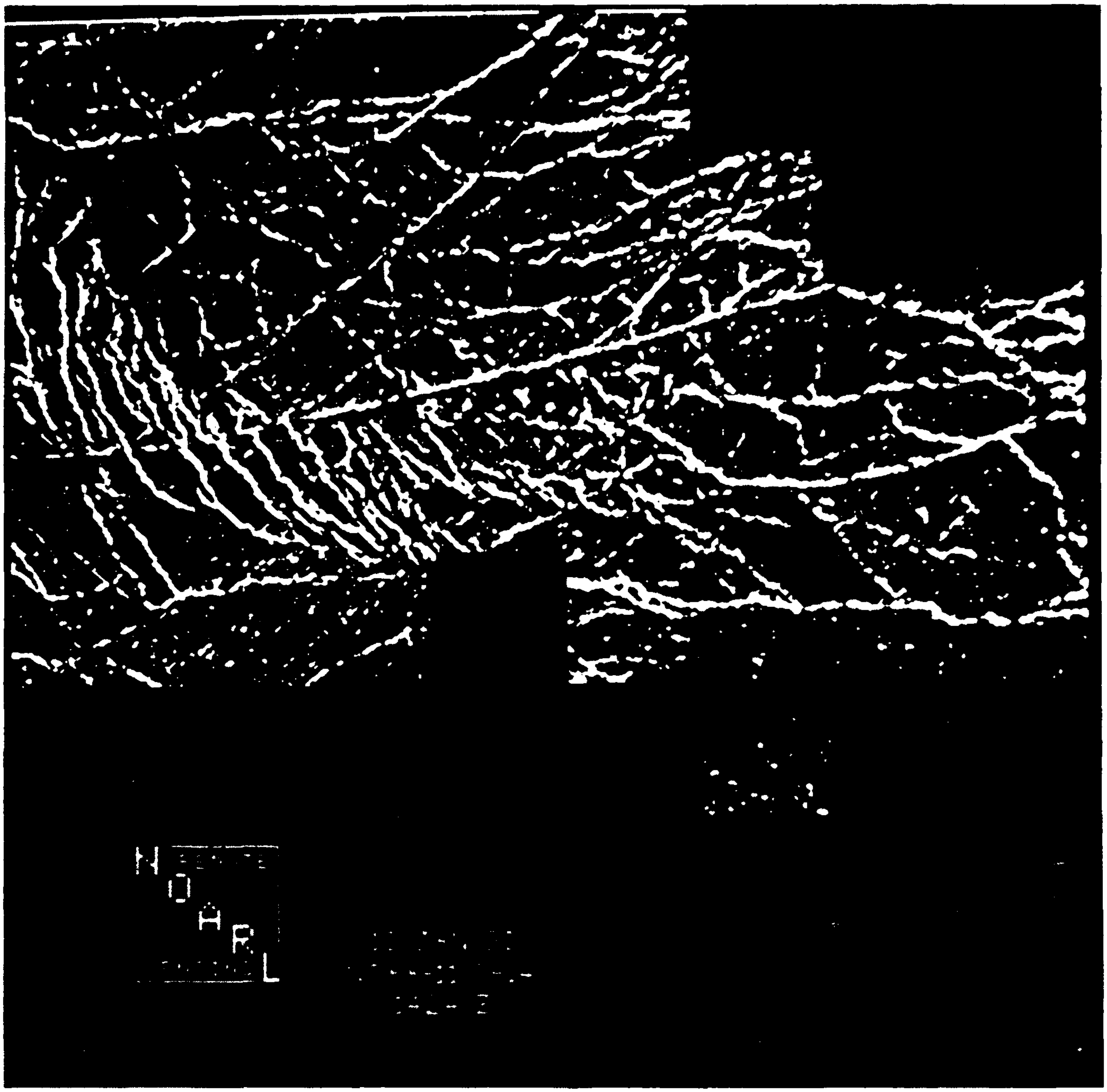
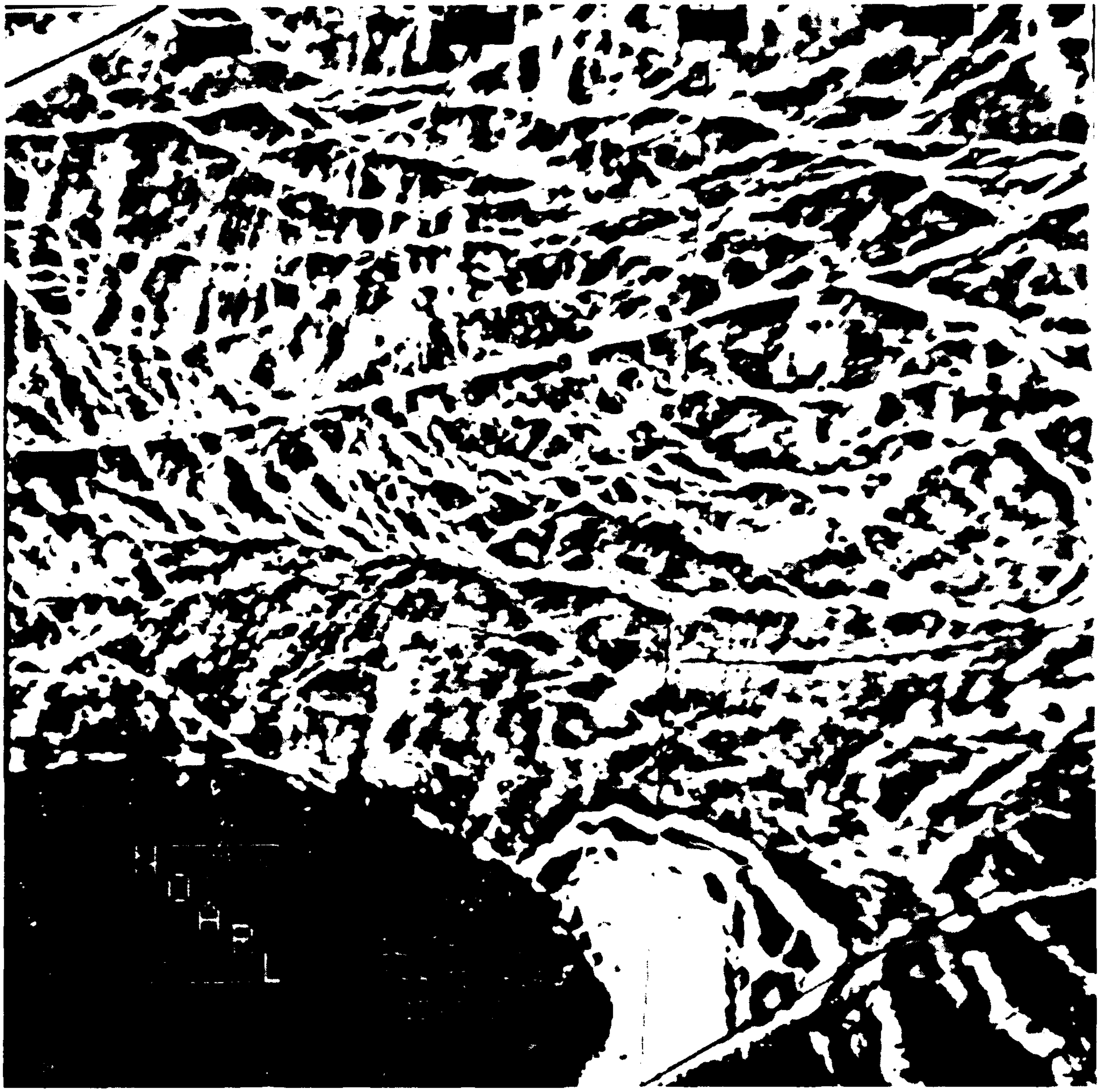


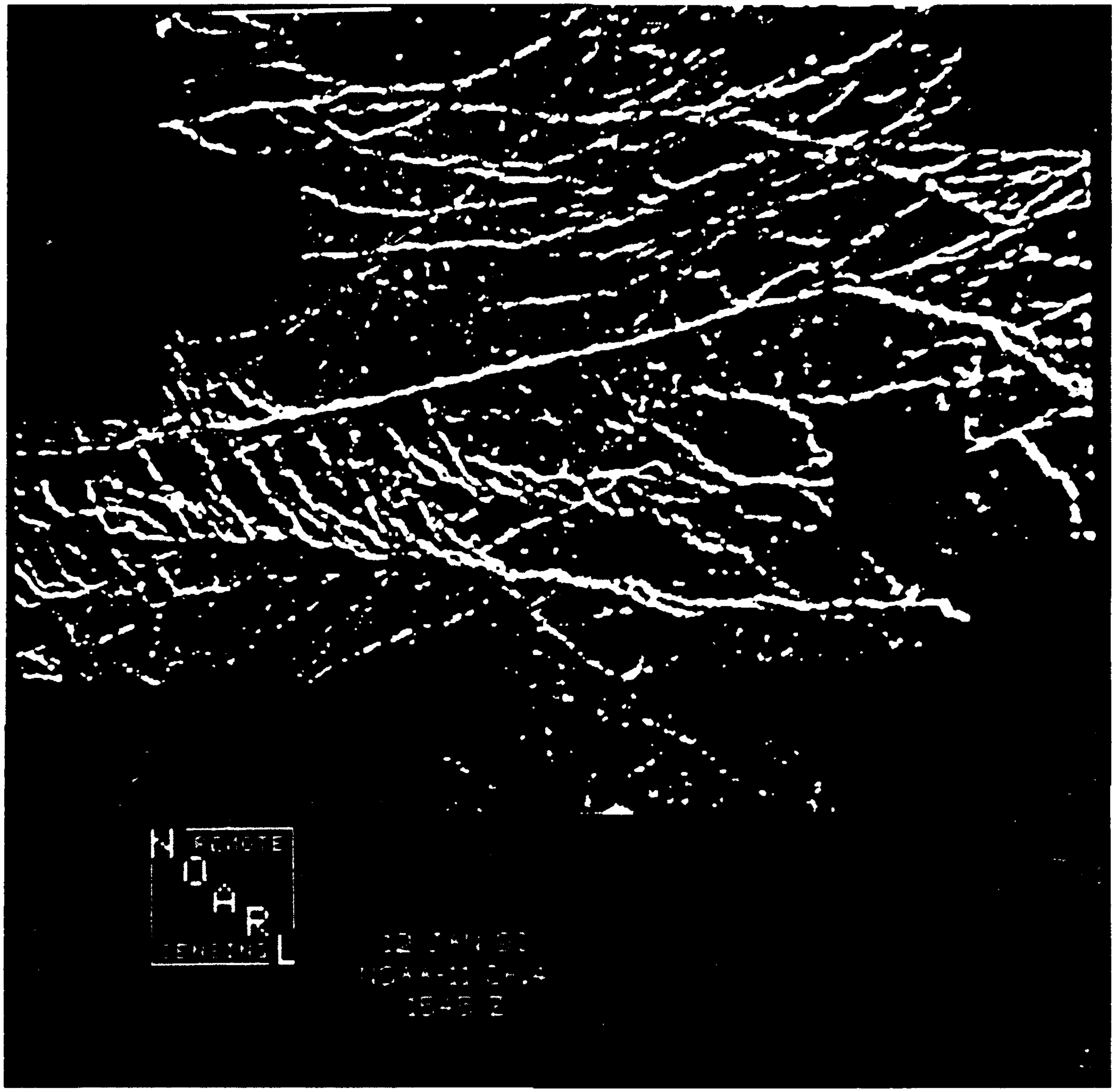
Region 4 250 Hz







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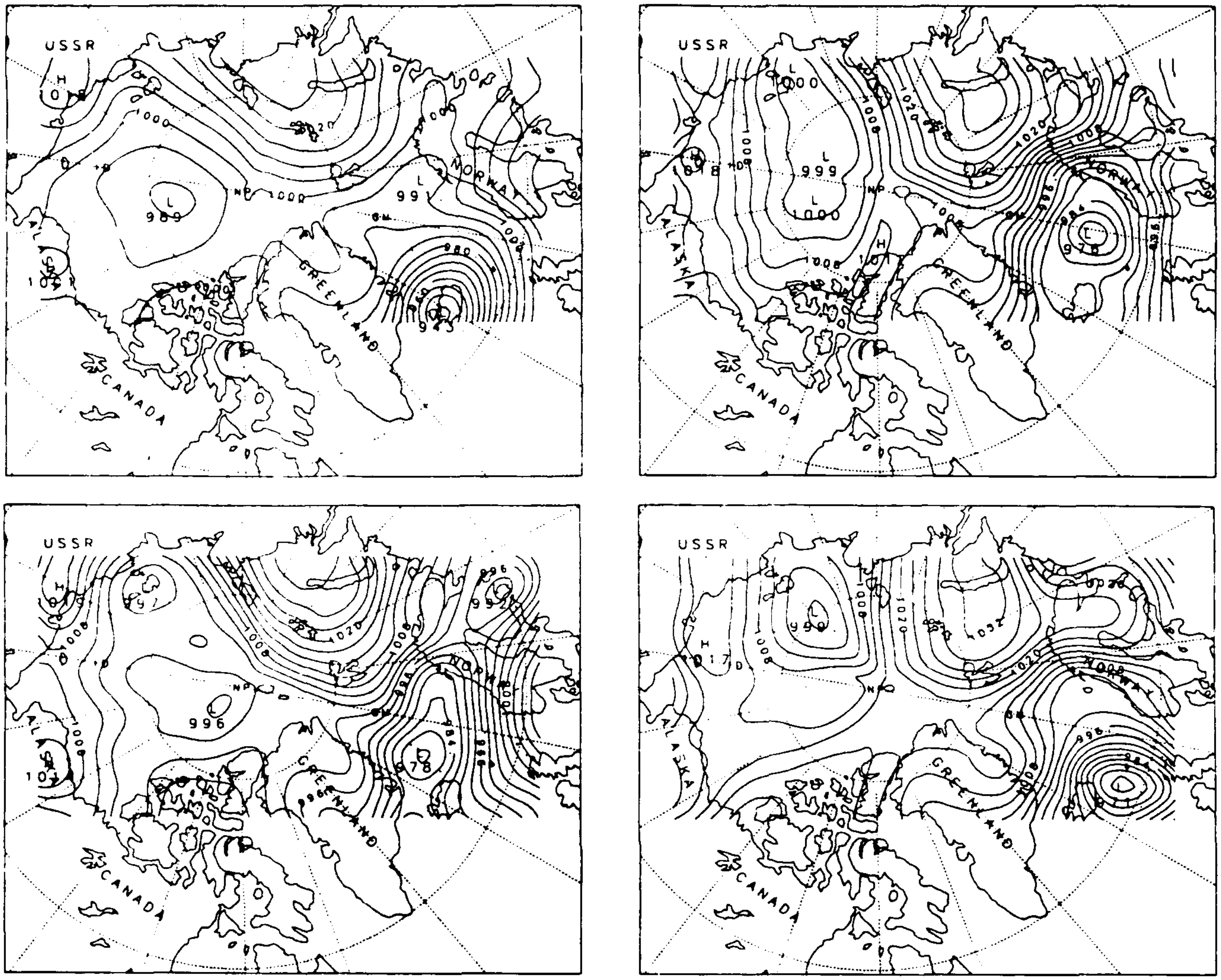
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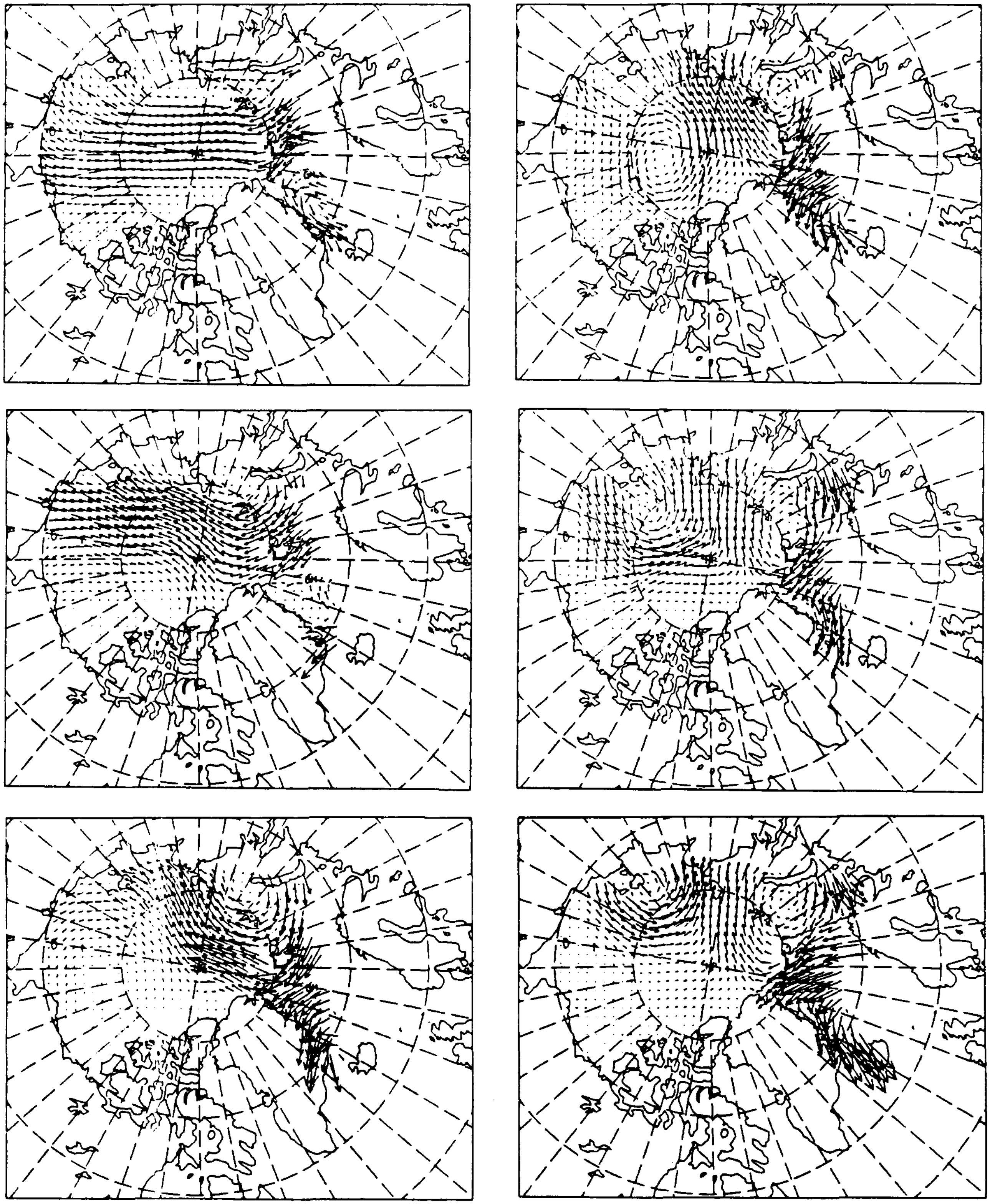
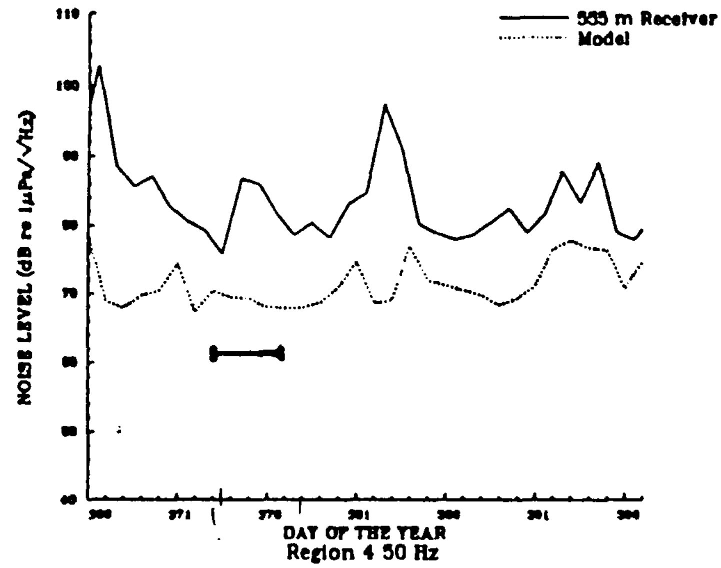


Region 4 15 Hz



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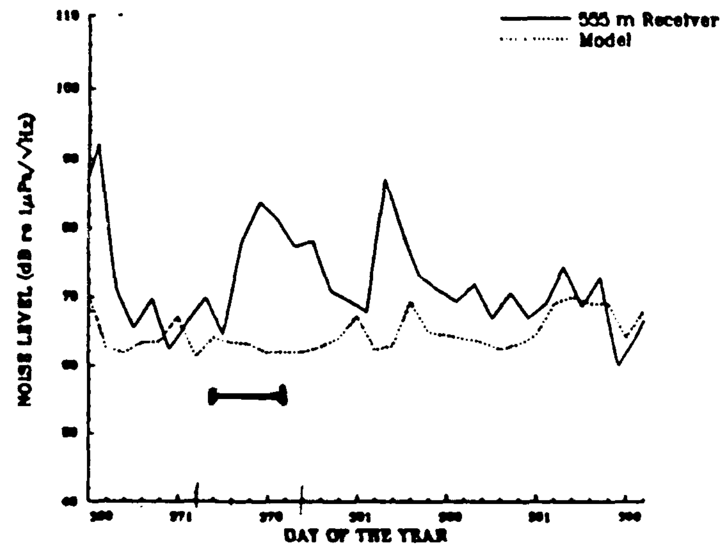
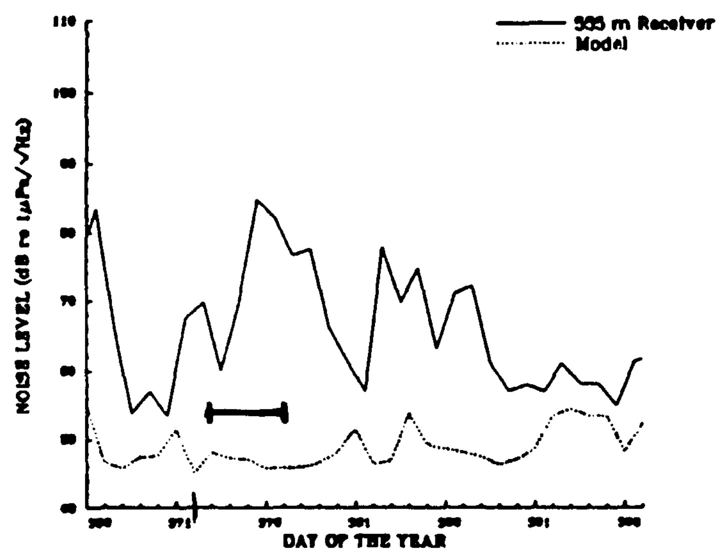
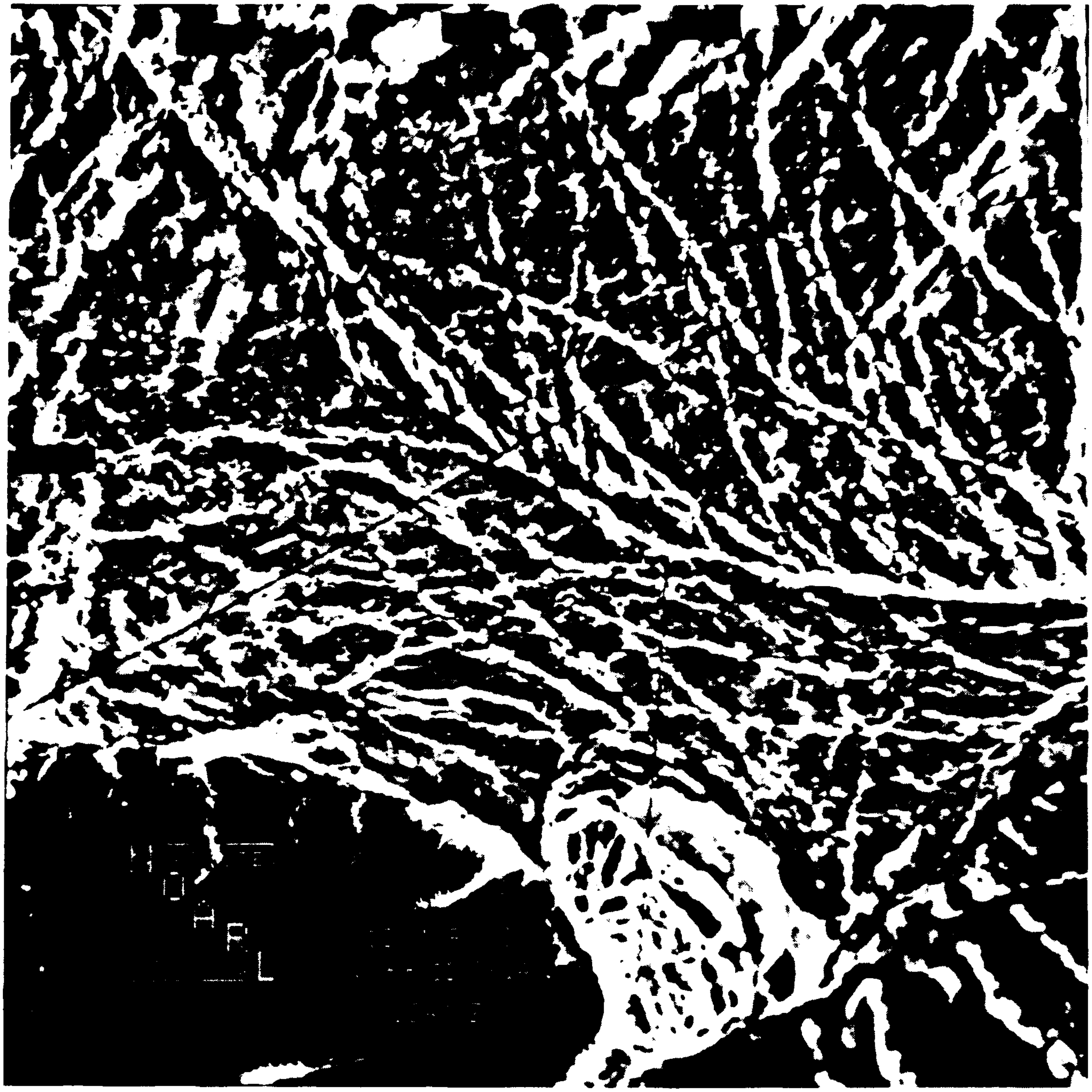
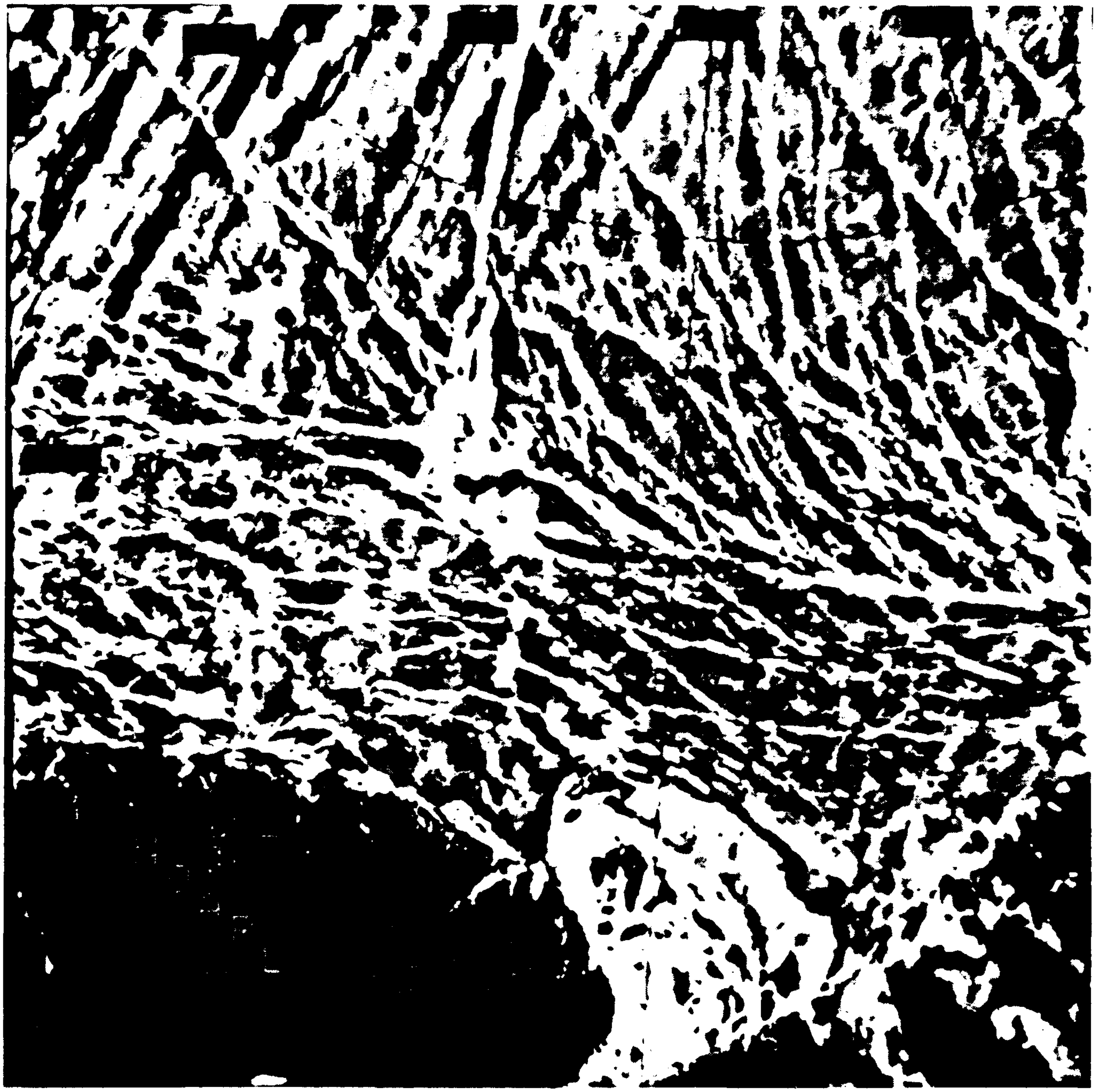
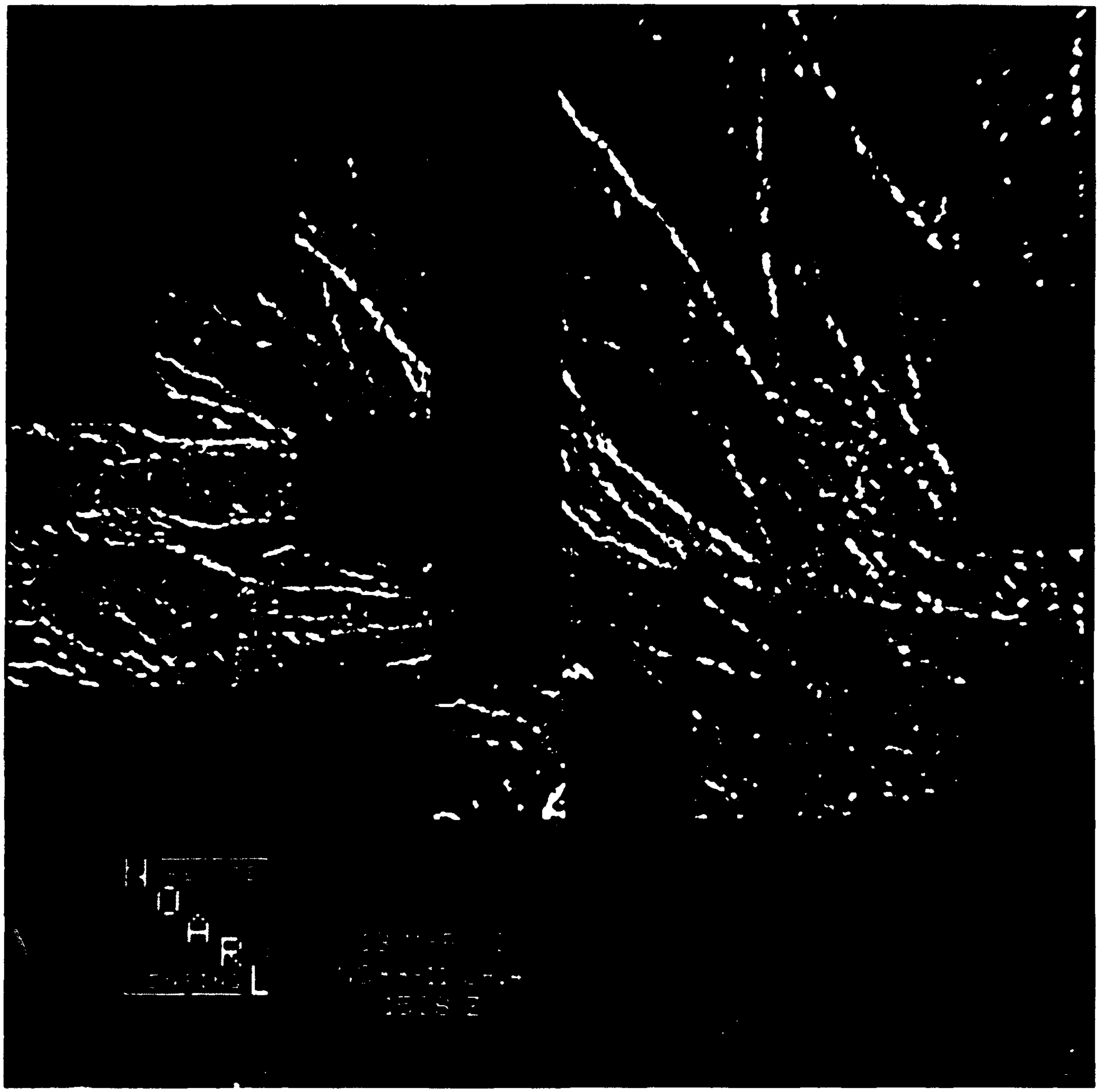


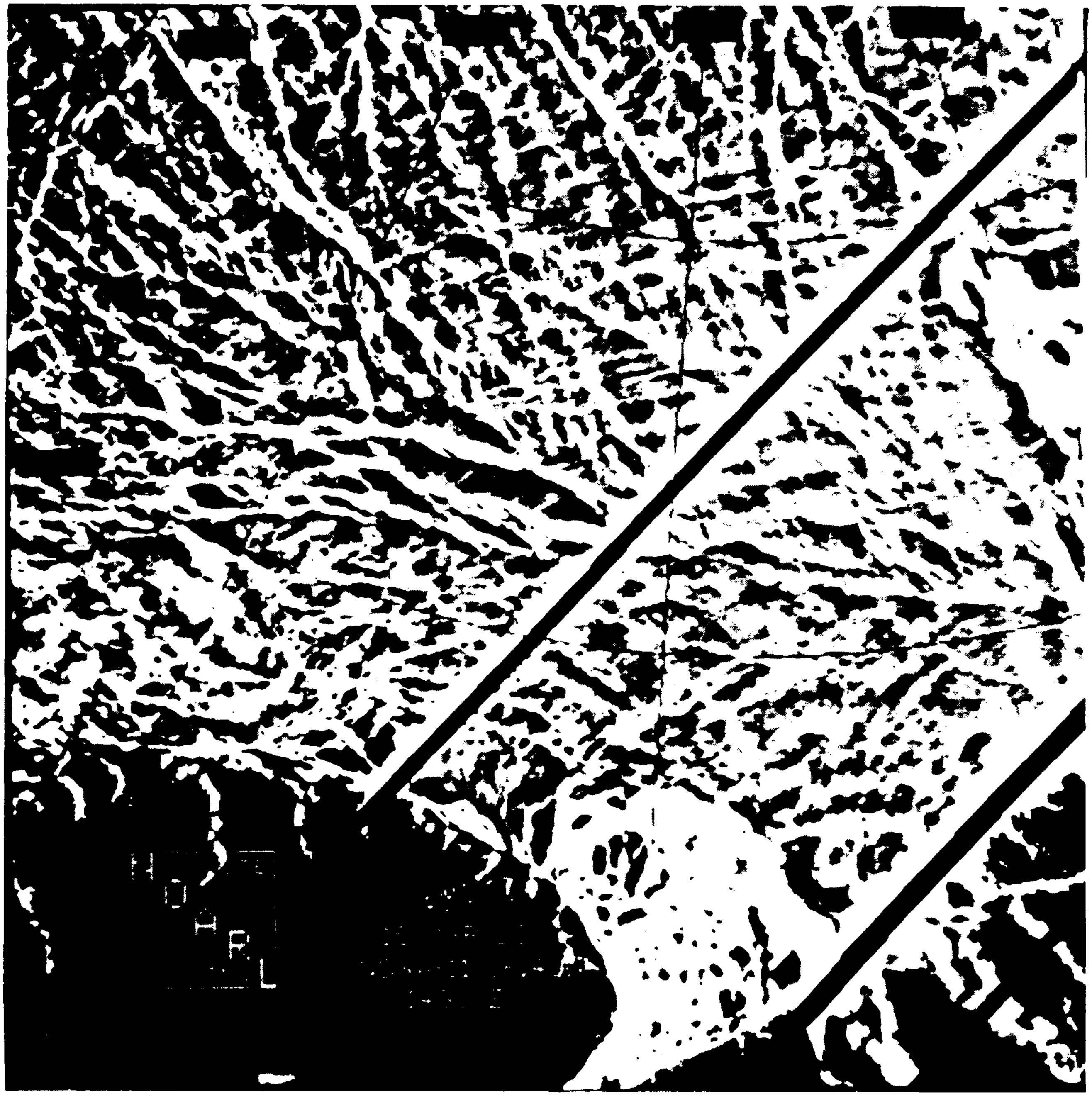
Region 4 250 Hz

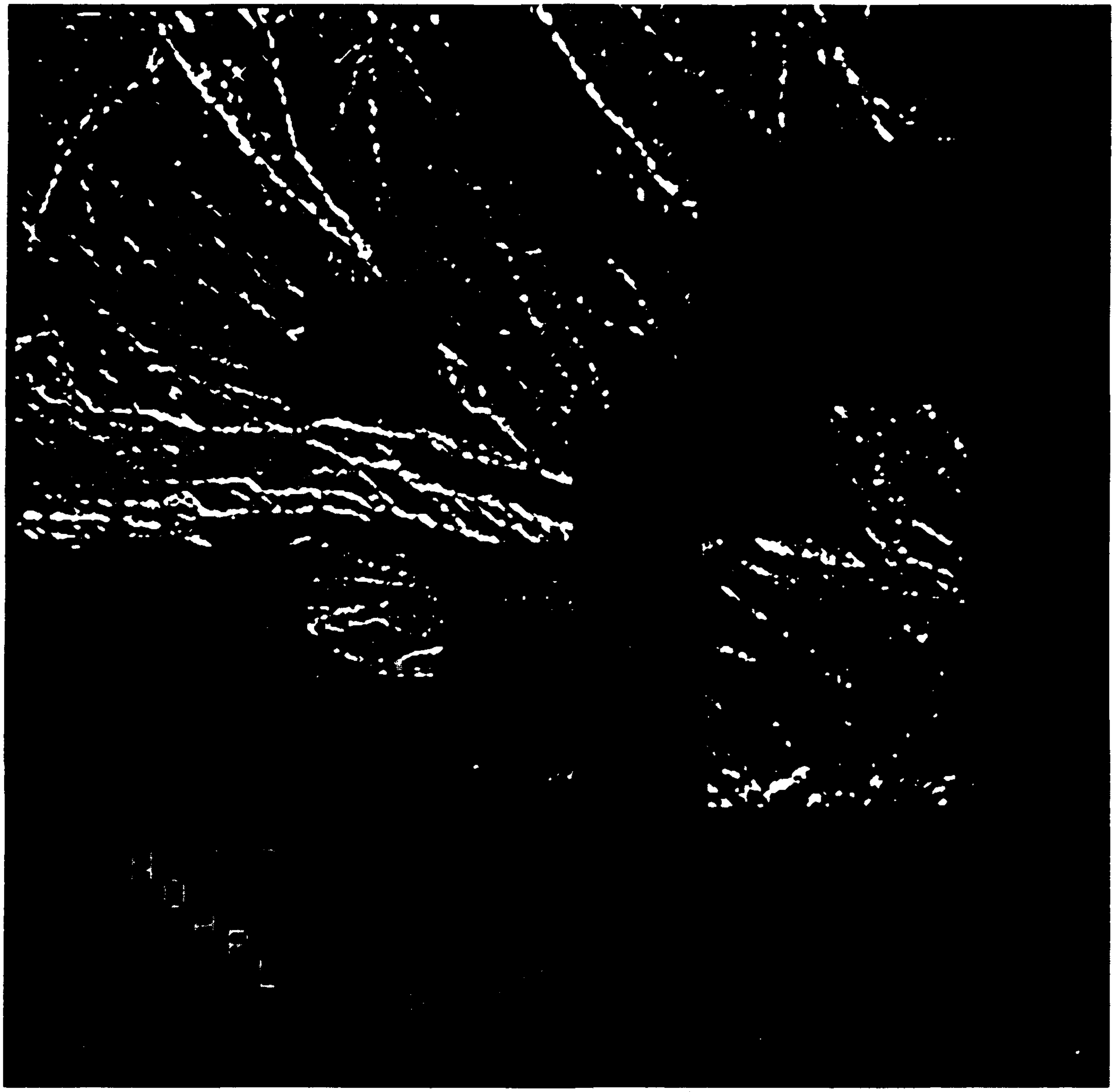


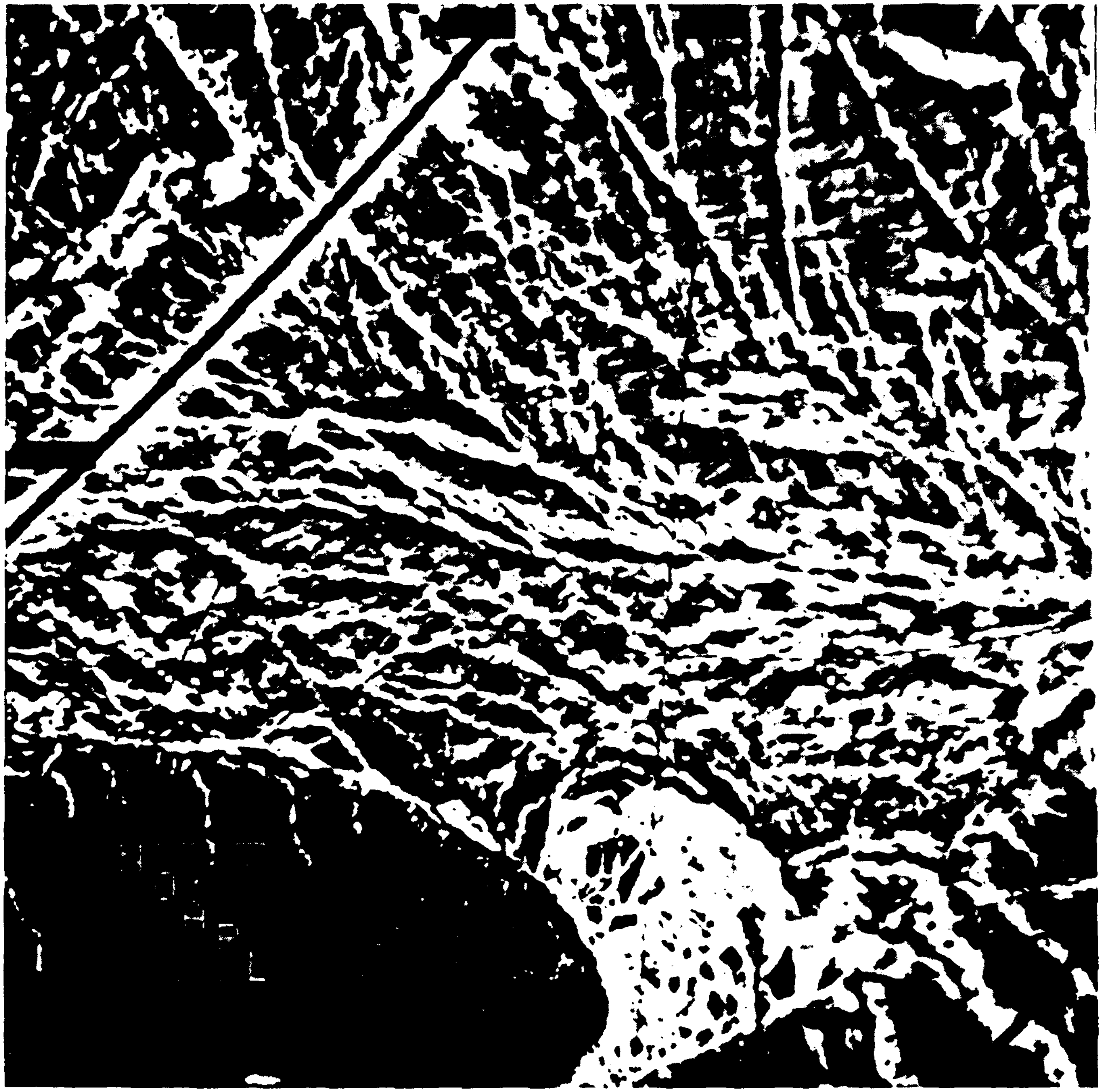


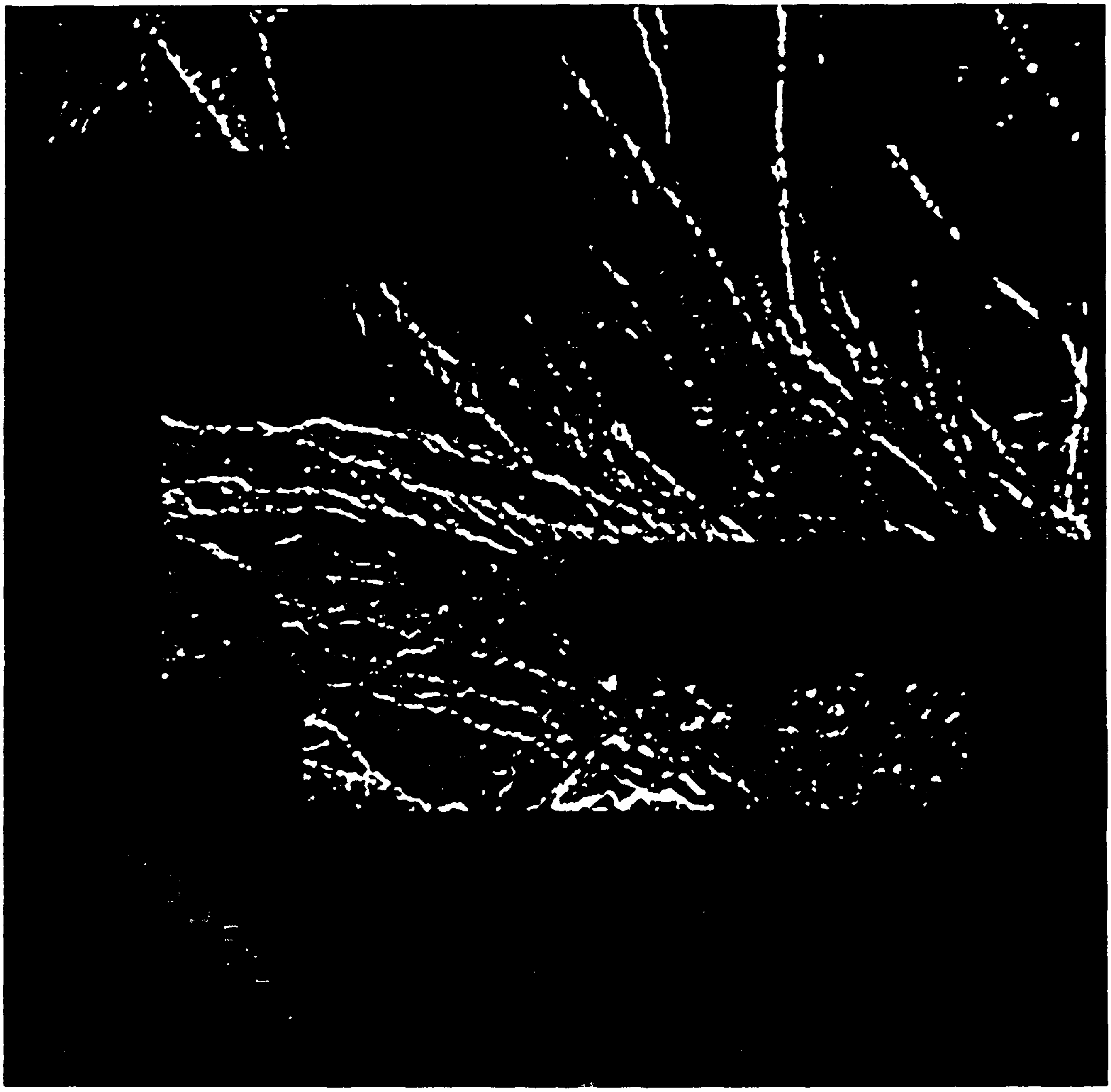










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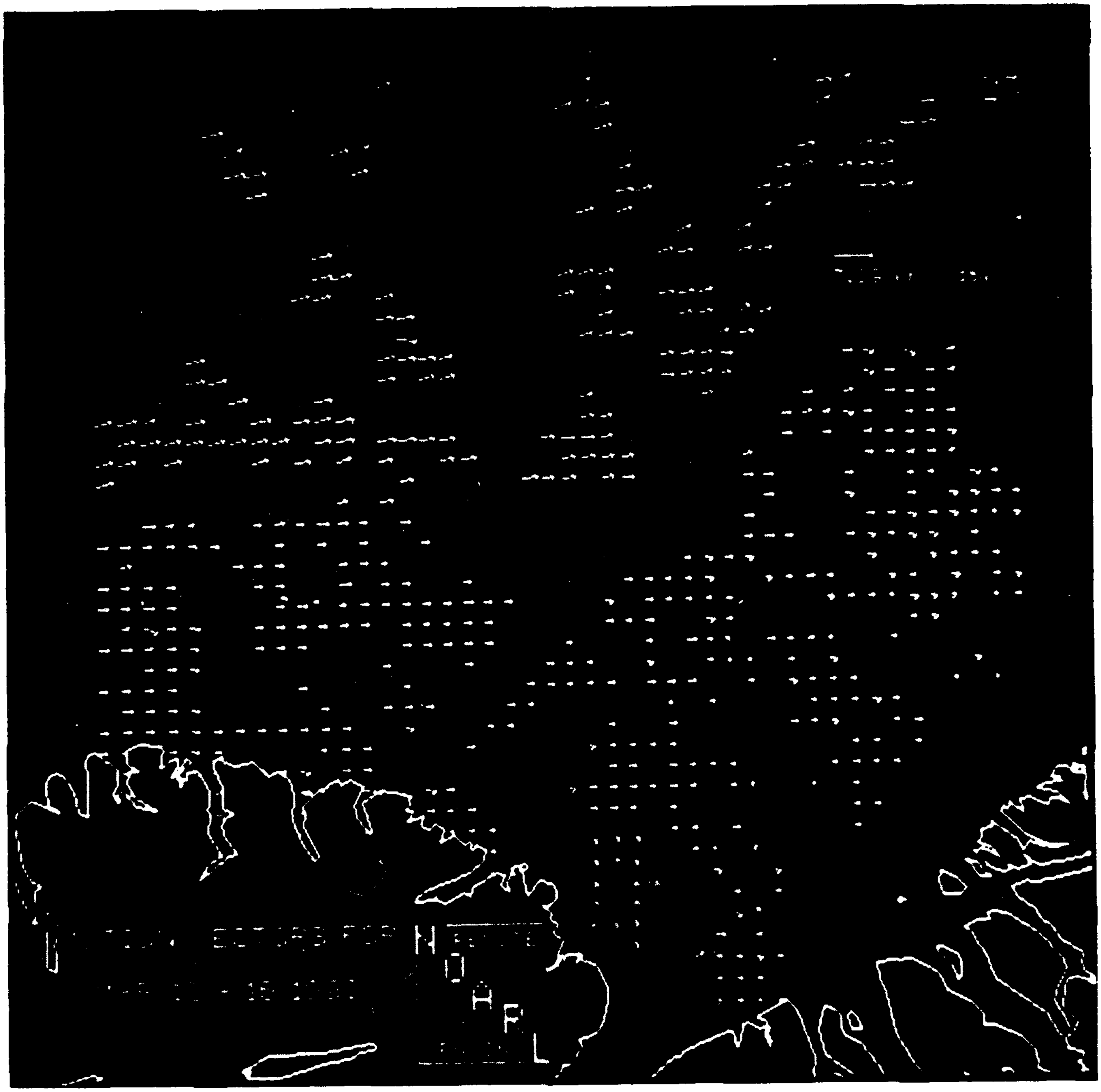
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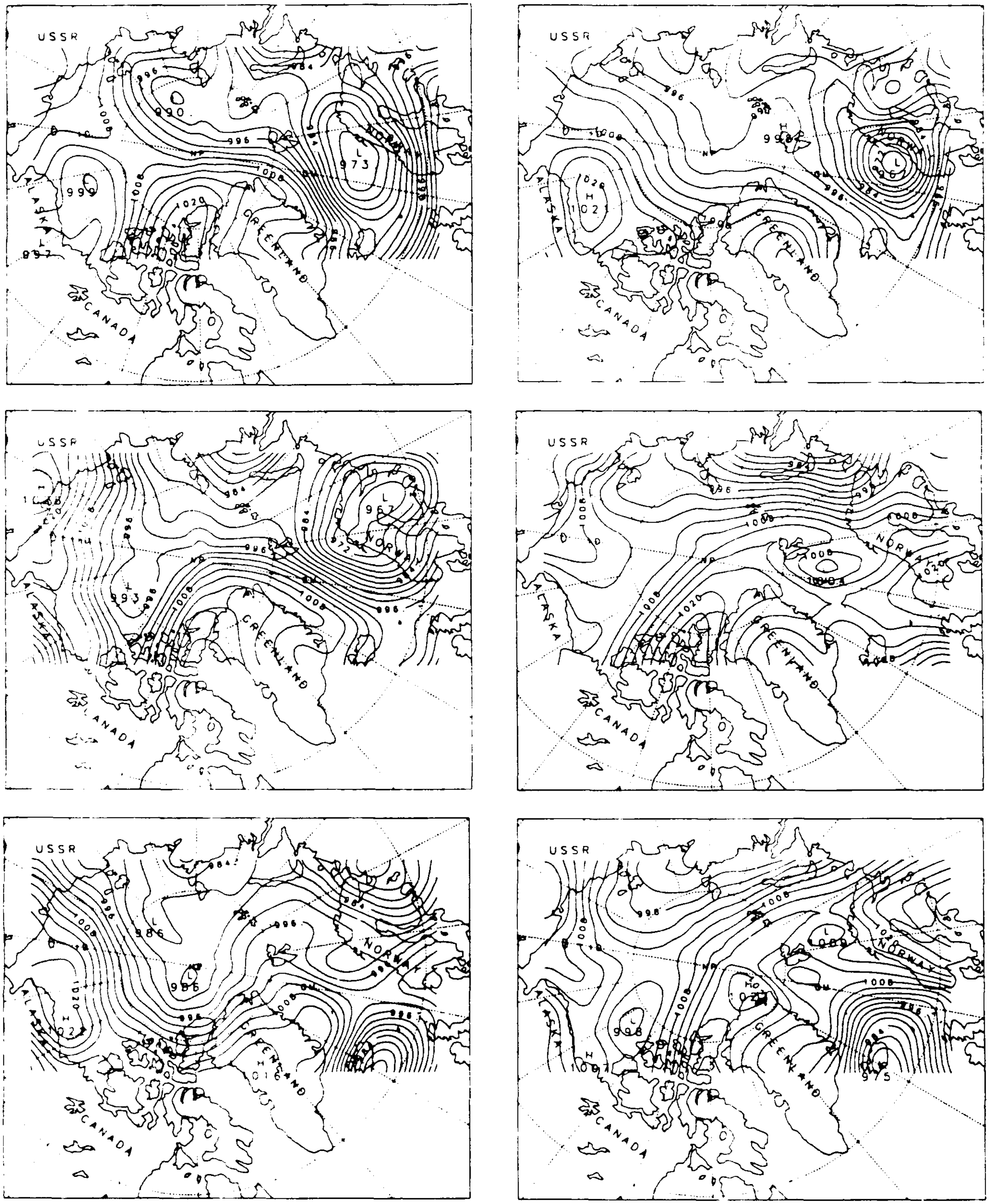
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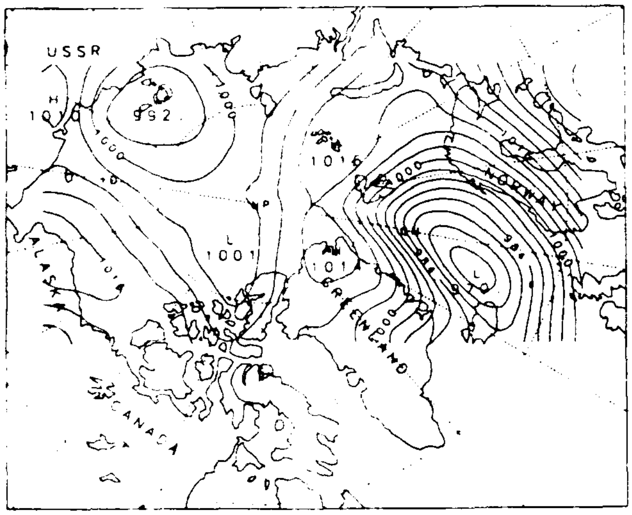
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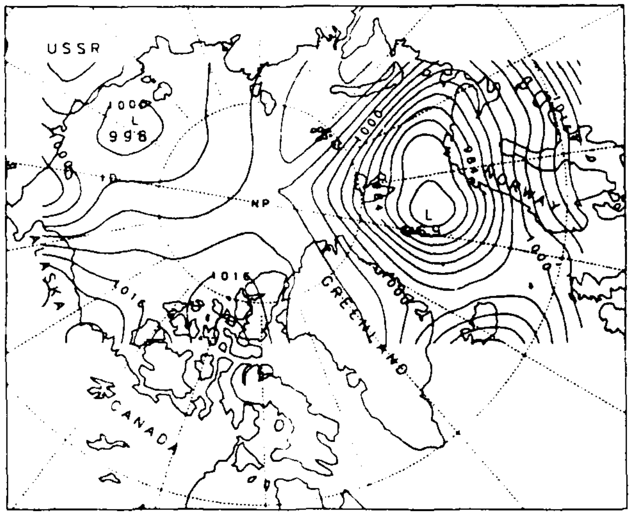
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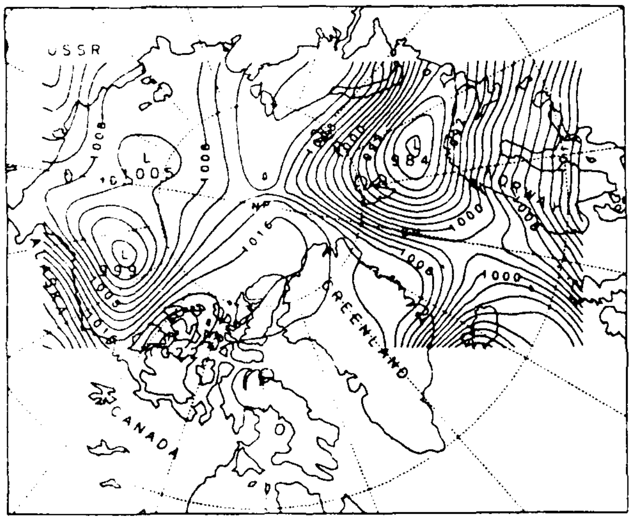
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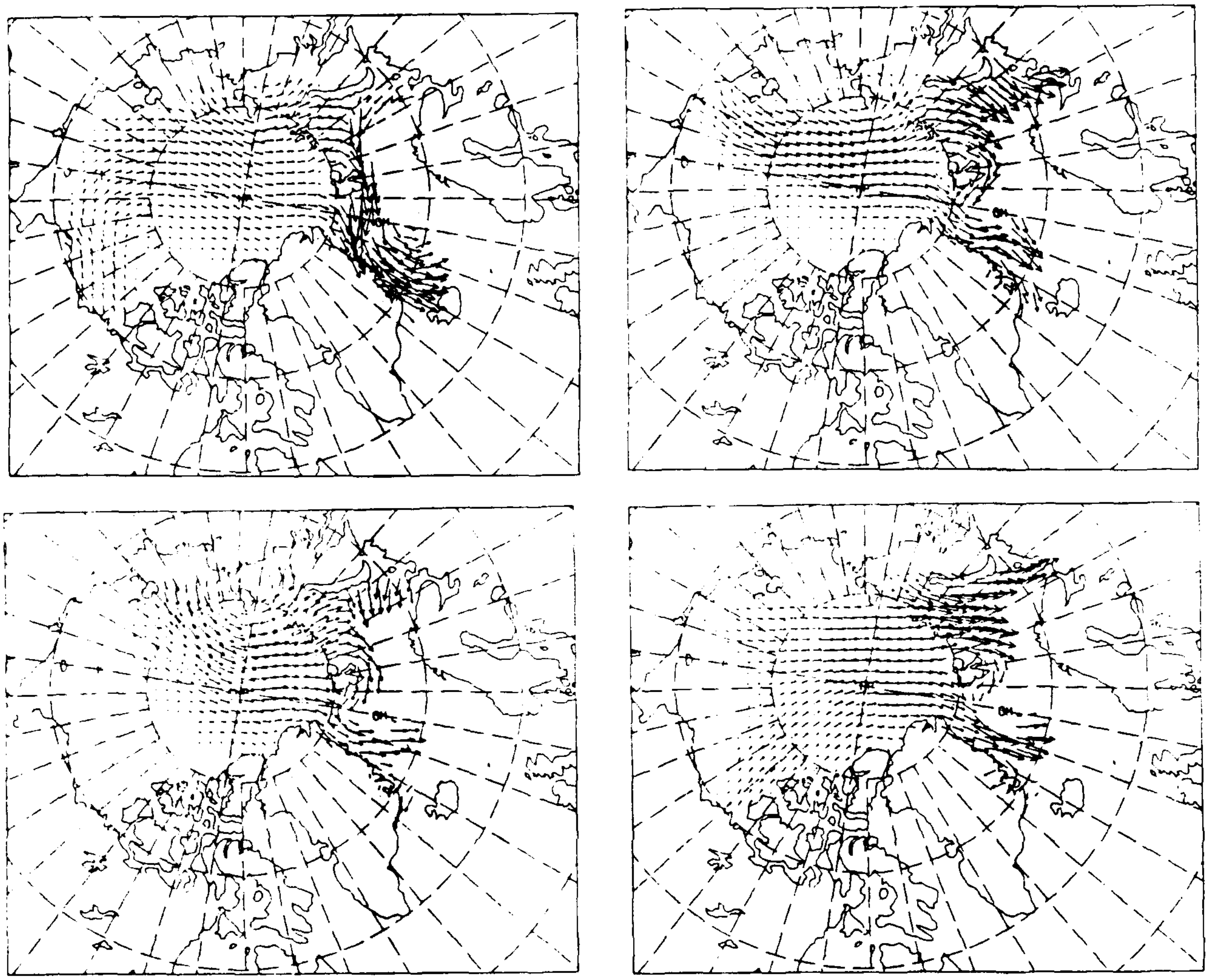

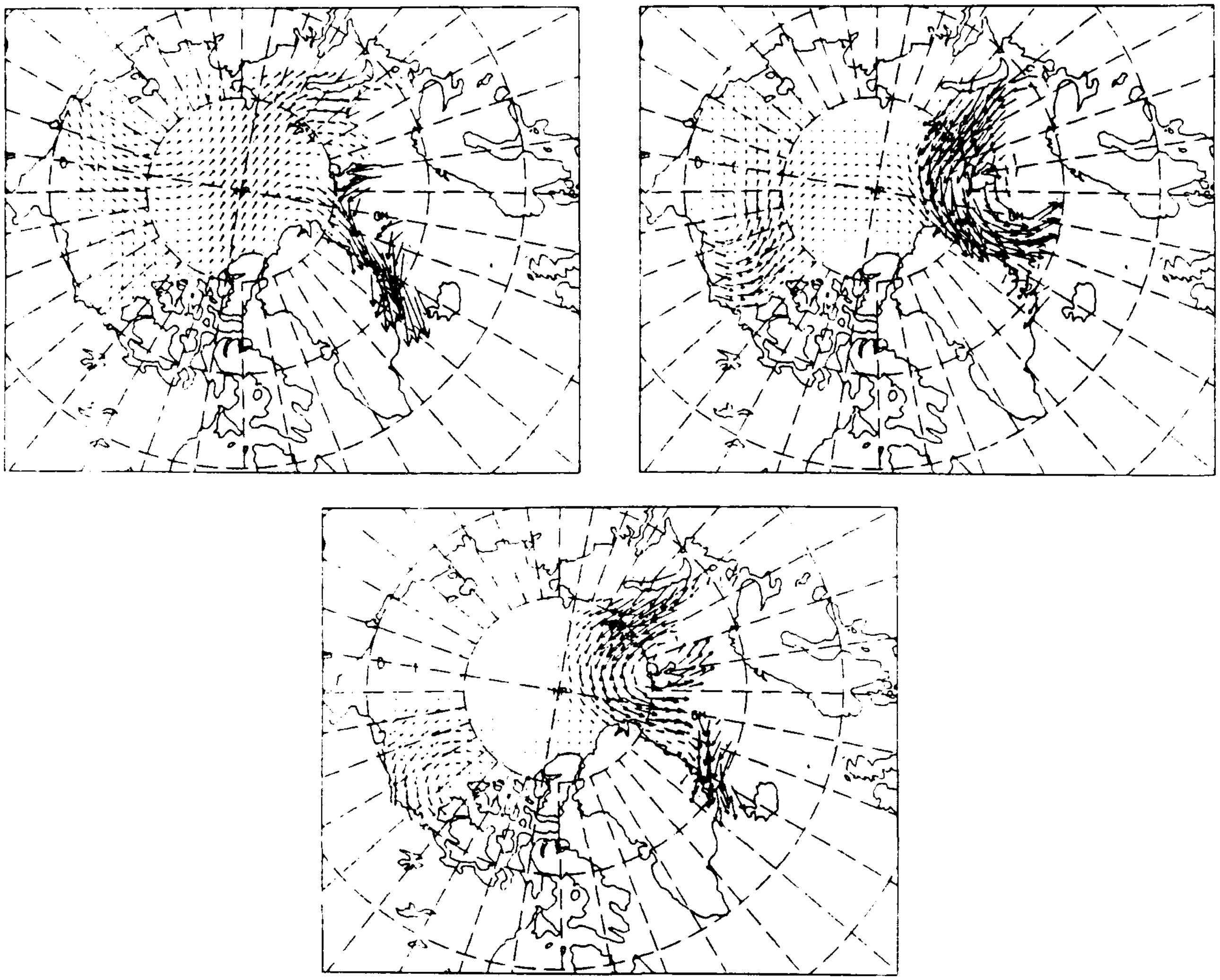

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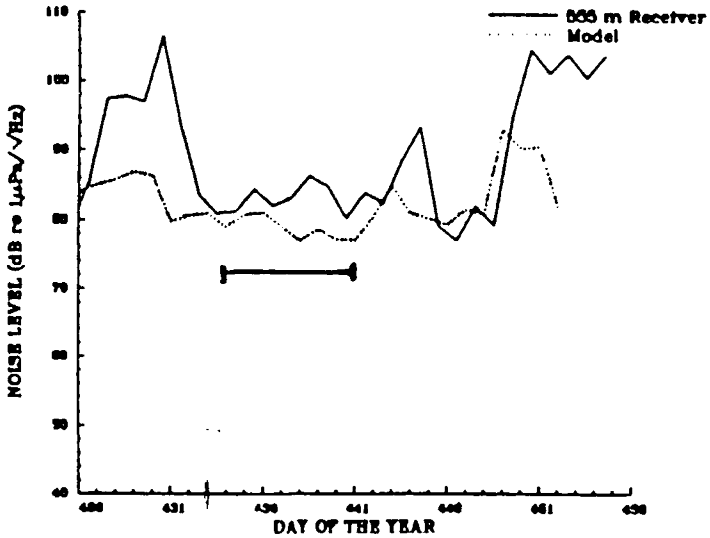

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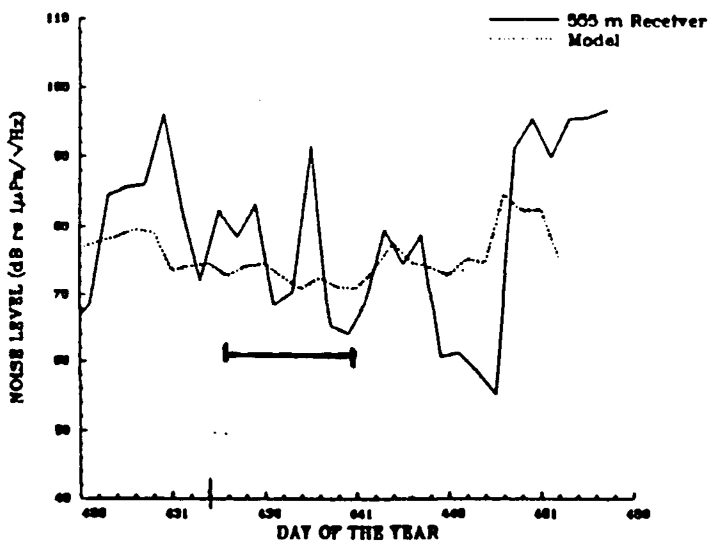
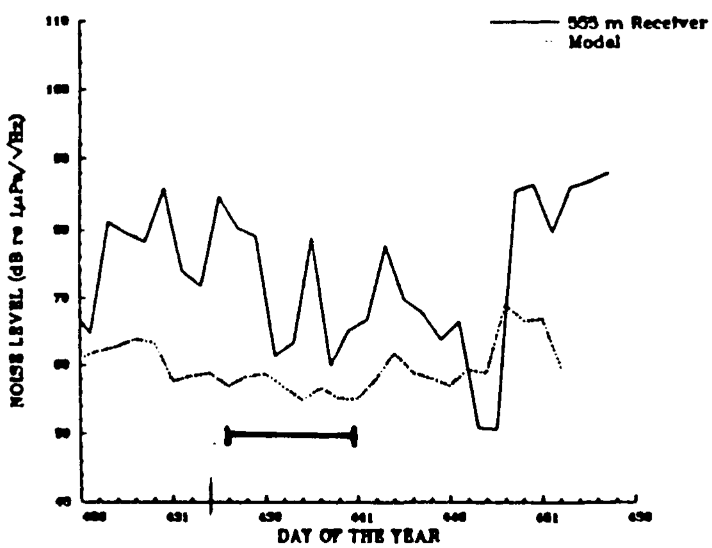


Region 4 250 Hz



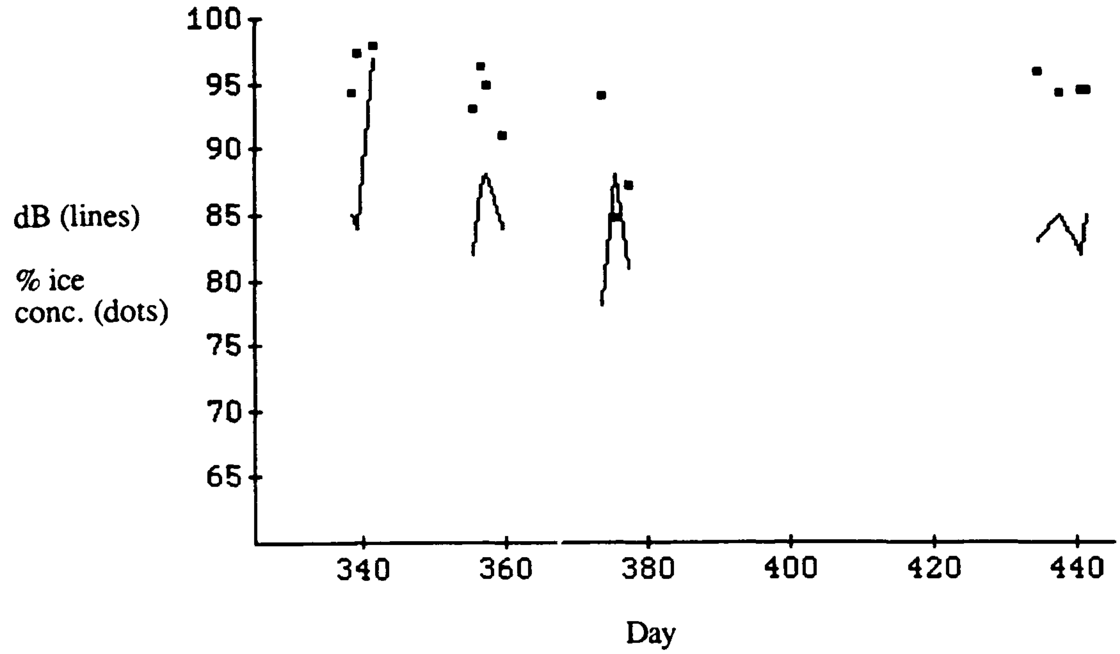


Figure 52. Daily Ambient Noise at 15 Hz (solid lines) in dB and Percent Ice Coverage (dots) for December, January, and March Common Blocks.

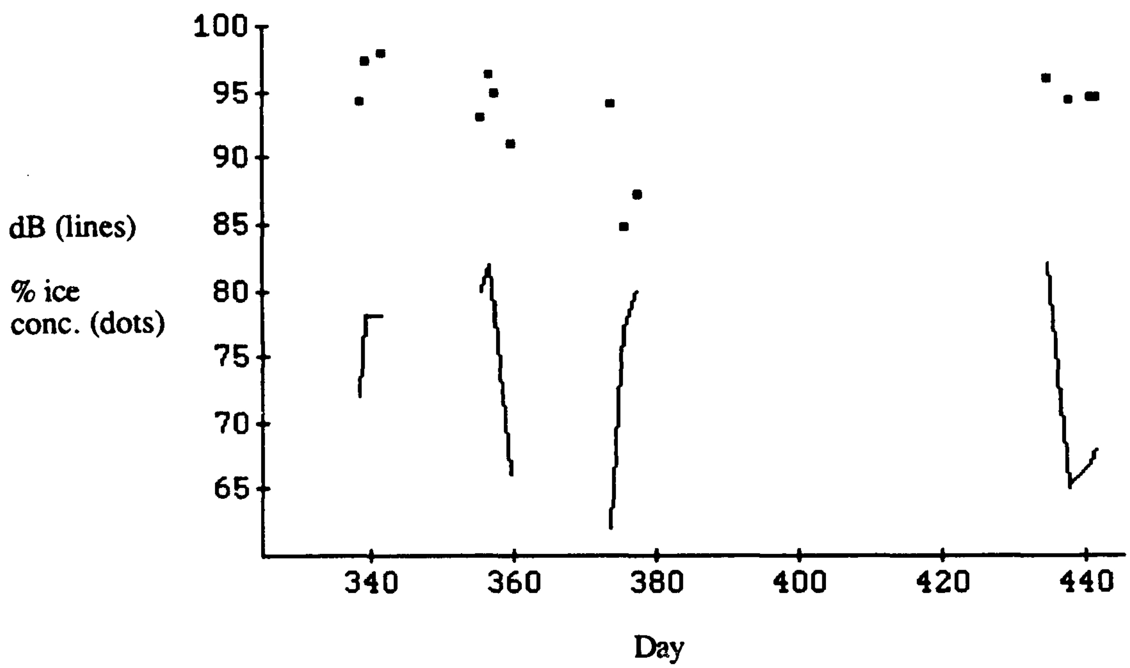


Figure 53. Daily Ambient Noise at 50 Hz (solid lines) in dB and Percent Ice Coverage (dots) for December, January, and March Common Blocks.

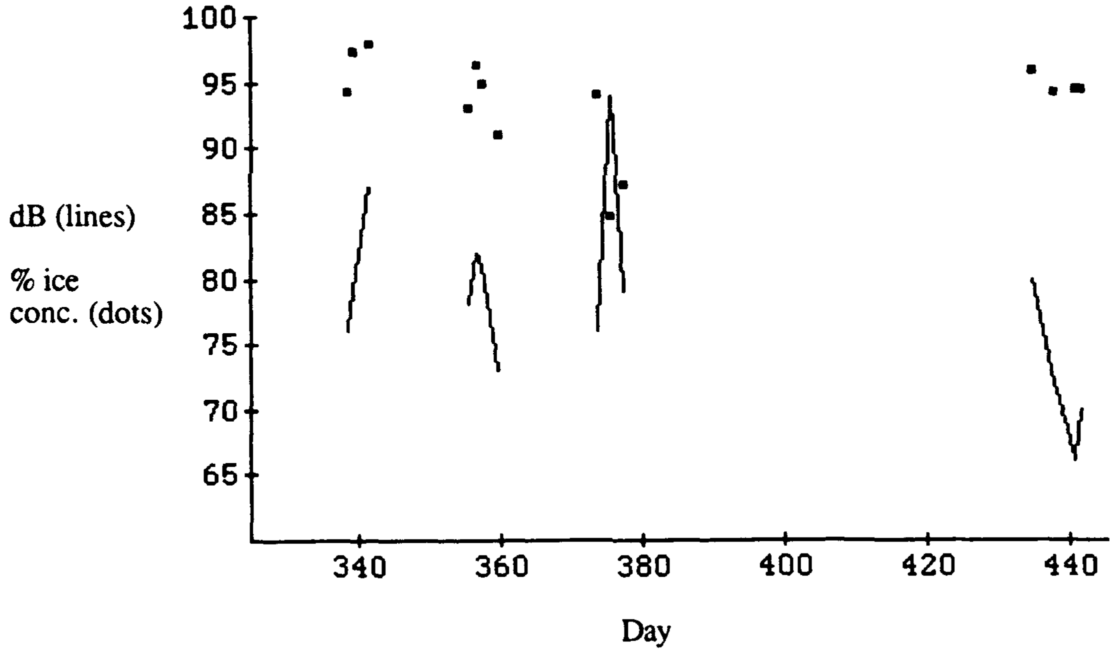


Figure 54. Daily Ambient Noise at 50 Hz (solid lines) in dB and Percent Ice Coverage (dots) for December, January, and March Common Blocks.

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13. Abstract *(Maximum 200 words).*

During the Naval Oceanographic and Atmospheric Research Laboratory (NOARL) Winterover experiment of 1989-1990, satellite imagery was processed in order to compare ice parameters derived from the imagery with the acoustic data collected. This effort is a continuation of an investigation of techniques developed during the Lincoln Sea exercise of 1990 (Fetterer et al., 1990).

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